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Focus on Friends

The Goldfields Naturalists' Club Inc.

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Beginnings

> A club "to provide people interested in natural history with the opportunity to meet and learn from other people with both similar and diverse interests in the Goldfields environment".

These introductory words are from a press release published in March 1987 announcing the formation of the Goldfields Naturalists' Club.

The inaugural meeting of the Club was held on 5 December 1986 and amongst the attendees were Chris Tate, Ken Mills, Wally Klau and David Pearson, all of whom had a great interest in the natural history of the Goldfields region and were keen to find like-minded people and raise awareness of the extraordinary natural environment right here on the doorstep. Office bearers appointed at the meeting were Club President – Ken Mills, Treasurer – Wally Klau, and Secretary – David Pearson. Chris Tate was recognised for his enthusiasm and organisational ability in helping form the Club and was thanked and farewelled in a notice in the first Goldfields Naturalists' Club Bulletin in 1987 as he was transferred to Karratha for his work. Chris joined the Nicol Bay Naturalists' Club and organised for the two clubs to exchange newsletters.

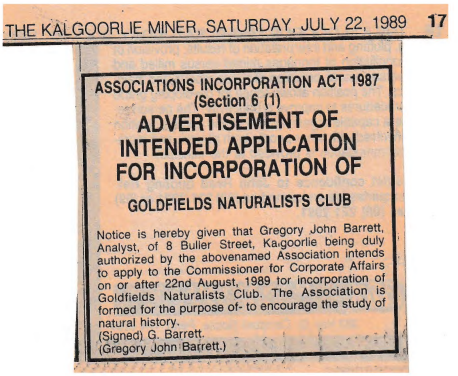
In addition to the founding members, it was noted that the Club had a broad base of skilled professionals including Greg Barrett, Andrew Chapman and Erich Lassak, as well as talented amateurs such as Michael Blythe and Lois and Bill Powlesland.

In the *Goldfields Naturalist Club – Bulletin Two,* a comment was made on the value of having local input into fauna and flora research because "in the past, research work has been conducted from Perth, severely limiting the number of times an area may be visited". Concern was expressed at the lack of environmental awareness amongst children in Kalgoorlie with a view to rectifying this through the activity of the Club.

In establishing this naturalists' club, the founding members determined it should be independent of, but maintain an association with the WA Naturalists' Club and other similar organisations. The Club organised to exchange newsletters with groups such as the WA Naturalists, the Nicol Bay Naturalists Club and the Leinster Naturalists Club. They also maintained contact and joined in with a like-minded club based in Esperance.

Incorporation

The Club organised to become incorporated within a couple of years of its formation (Fig. 1). Early records show the correspondence leading to the drafting and then formal adoption of the first constitution on 2 June 1989. It was amended on 3 November 1989 and again on 6 September 1991. The Certification of Incorporation under the Associations Incorporation Act 1987 was issued on 14 September 1989. The Club continued under the amended constitution until legislative changes in Western Australia led to the need to change to Rules of Association. The Club made minor changes to *the* previous constitution and the new Rules of Association were adopted on 4 April 2020.


THE KALGOORLIE MINER, SATURDAY, JULY 22, 1989 17

ASSOCIATIONS INCORPORATION ACT 1987
(Section 6 (1)
ADVERTISEMENT OF
INTENDED APPLICATION
FOR INCORPORATION OF
GOLDFIELDS NATURALISTS CLUB

Notice is hereby given that Gregory John Barrett, Analyst, of 8 Bulier Street, Kalgoorlie being duly authorized by the abovenamed Association intends to apply to the Commissioner for Corporate Affairs on or after 22nd August, 1989 for incorporation of Goldfields Naturalists Club. The Association is formed for the purpose of- to encourage the study of natural history.
(Signed) G. Barrett.
(Gregory John Barrett.)

Figure 1. Notice in Kalgoorlie Miner newspaper advertising Club's incorporation.

Membership

The membership has varied over the years and members come from all walks of life. The Club has embraced ecologists, mining engineers, geologists, plumbers, teachers, health professionals, pastoralists and artists, all with a strong interest in natural history. Regardless of background, each member contributes within their area of expertise or interest which makes for interesting meetings and excursions. Recruiting new members is an ongoing challenge and one that is faced by many other local clubs and associations.

Newsletter

The Goldfields Naturalist Club "Bulletin" began with the first meeting and has continued in different formats. The records from the early meetings show that some time was invested in selecting a Club logo and a name for the Club's newsletter. Club members were encouraged to submit drawings and ideas for the logo. Mavis Quartermaine submitted a selection of different options and ultimately her drawing of *Eucalyptus torquata* was chosen (Fig. 2).

After some debate over the title for the newsletter, it was decided to use the title "Goldnats News" (Fig. 3). The logo and newsletter title continue to be used to this day.

Publicity

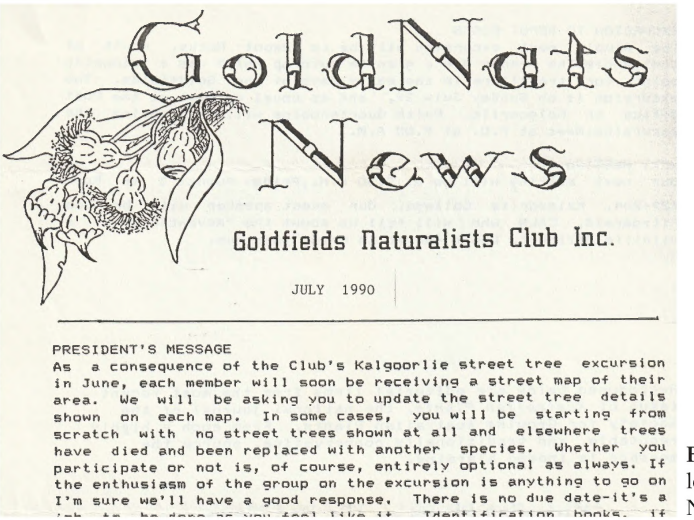
To start with the Club relied on printed flyers displayed in local shop windows,

Figure 2. *Eucalyptus torquata* drawing by Mavis Quartermaine.

radio announcements, word of mouth and a hard copy of its newsletter to promote the meetings and activities of the Club. As society has become reliant on electronic media, printed correspondence has gradually declined to almost nothing. Newsletters and notices are now sent via email, and in more recent years with the increase in popularity and accessibility of social media, the Club has set up a Facebook page. Facebook is now used to promote the Club's activities and to invite members of the public to contribute relevant photos or stories for posting on the Club's page. It has enabled the Club to achieve a broader public exposure than was previously possible. New interest and memberships have resulted from these steps.

Meeting venue

From the time of the inaugural meeting, the Club used a meeting room at what was then known as Kalgoorlie College (now Central Regional TAFE – Kalgoorlie Campus). The Club was able to use the room free of charge and the College arranged for the room to be unlocked for the meetings, and locked afterwards. This worked well for many years, although occasionally there were challenges in arranging equipment like data projectors and coffee and tea-making facilities.



GoldNats News

Goldfields Naturalists Club Inc.

JULY 1990

PRESIDENT'S MESSAGE

As a consequence of the Club's Kalgoorlie street tree excursion in June, each member will soon be receiving a street map of their area. We will be asking you to update the street tree details shown on each map. In some cases, you will be starting from scratch with no street trees shown at all and elsewhere trees have died and been replaced with another species. Whether you participate or not is, of course, entirely optional as always. If the enthusiasm of the group on the excursion is anything to go on I'm sure we'll have a good response. There is no due date-it's a

Figure 3. Early newsletter of the Goldfields Naturalists' Club.

An opportunity came up to move to the Sandalwood Family Centre for meetings. This involved paying a room hire fee but provided excellent facilities including a data projector and screen, large meeting rooms, lockers and kitchen facilities. Additionally, groups using the facilities were allocated a key to simplify access arrangements. Any doubts about the decision to change venues were quickly dispelled when, after one meeting at the Kalgoorlie College facility, the Club members found themselves *locked in* by an over-enthusiastic security officer. In 2009, the Club moved its meetings to the Sandalwood Family Centre venue permanently and has not looked back.

Meetings

At the Club's formation, the founding members organised to hold monthly meetings and regular excursions and to participate in a range of research projects and flora and fauna surveys. Suggested topics for the meetings included bird banding and migration, the sandalwood industry, the kangaroo management programme, geology and mining, rehabilitation of injured wildlife, native plants and their cultivation and the management of conservation and grazing lands. It was anticipated the Club would work closely with wildlife research personnel from the Department of Conservation and Land Management (CALM) to conduct bird counts, bird banding, plant identification and live-release reptile and mammal trapping programmes.

The Club continues to meet monthly. The format is much the same as in the early days, with a guest speaker or a club member presenting a talk on a topic of naturalist interest, followed by the general meeting and supper. It is not possible to access a guest speaker for every meeting however, there is usually a club member happy to step in and do a presentation. Club nights are also a popular option in which all members are invited to bring along and discuss something on the month's topic.

Various strategies have been used over the years to determine topics for meetings and the newsletter. For some years we made our way through the alphabet inviting members to bring along items or stories of naturalist interest beginning with a particular letter. Another strategy was to select a theme colour for the month and invite naturalist contributions related to that month's colour.

Photography has been of great interest within the Club since its inception, and a regular photo competition was established in the first year and continues today. Developments in digital photography have opened up opportunities for most people to "have a go", whereas in the past it might have been limited to those prepared to invest in specialised camera equipment. The photo competition is currently an amateur one and is held in December at the last meeting of the year. The challenge of presenting a great photo is still the priority but it is also an opportunity to reflect, through photos, on the activities of the past year.

Excursions and campouts

Kalgoorlie-Boulder is located in an area with access to a great diversity of environments. The choices are fascinating and nearly endless and

include the outstanding eucalypt woodlands of the Great Western Woodlands, the Mulga woodlands, the transition zone between eucalypt and mulga woodlands, extensive lake systems including ephemeral freshwater lakes and salt lakes, springs, granite outcrops, sandplains, breakaways, deserts and the Nullarbor.

Day trips have always been an important activity for the Club. Early records show the range of destinations for the outings extended in all directions from Kalgoorlie-Boulder. Places such as Karonie, Goongarrie, Comet Vale, Jaurdi Station, Majestic Timber Reserve, Peak Charles, Victoria Rock Nature Reserve, Caenyie Rock, Rowles Lagoon and the sandplain areas near Mt Burges are just some of the destinations that show up in the Club's records. The Club continues to visit all these locations and more.

Fine food has become a fundamental part of any excursion or campout! Not only does an extensive morning tea (Fig. 4) provide just the right nourishment after climbing a granite rock or walking the length and breadth of a salt lake, it also provides an ideal opportunity for discussion around everything from the tiny orchids on display to solving the world's problems. Supper after monthly meetings has been a feature since the Club was formed, although they might have become a little more elaborate over time. In any case, gathering around a cuppa has an important place in socialising and continued discussion of interesting or controversial topics from the meeting.

Figure 4. A typical morning tea spread on a Club excursion. Photo: J. Kavanagh.

Campouts are also a popular activity that has been enjoyed by Club members since the Club's formation. Over the years campouts have provided opportunities to both carry out biological surveys contributing to scientific research and to enjoy the natural environment in the Goldfields region with like-minded people. Campouts are organised on most of the long weekends in the year except in January or December.

The choice of campout destinations is practically unlimited including the same options as for day excursions. The clear Goldfields night skies, well away from any light pollution, are a favourite aspect of the campouts. In recent years the Club had access to a large telescope which provided extraordinary views of planets, stars, constellations and galaxies to the delight of all members who attended. And, of course, a campfire in the right season is always a vital part of the campout.

Community involvement

It is clearly stated in the Club's Constitution (now the Rules of Association) that one of the objects is to "promote the study of natural history and promote interest therein". The Club endeavours to achieve this through meetings and excursions, but also through having stalls at local events such as market days, festivals and expos (Fig. 5). Two of the regular events are a Community Expo held each February which targets those new to town, and the Lorna Mitchell Spring Festival, a community-wide event. Both are large well-attended events providing an excellent opportunity to promote the Club.

One regular feature of the Club's stall is a quiz featuring local flora and fauna (Fig. 6). While many adults and children can identify most of the photos, it is alarming how many people are not able to recognise some

Figure 5. Goldnats stall at Boulder Markets. Photo: S. Alberro.

Figure 6. Winner of the competition at a Goldnats stall. Photo: S. Alberro.

Figure 7. Writing card sets by Goldnats members.

of the more common ones, including *Eucalyptus torquata*, the Club's logo!

In 2014 during preparation for a stall at a special arts event, the Club organised to have a specially-designed Silky Pear logo which was printed on a collection of t-shirts and hats. Additionally, a series of writing cards featuring photos by Club members was printed by a local business (Fig. 7). These items were well received at the arts event stall and continue to be very popular at more recent stalls.

Networks and projects

The Club has been involved with monitoring birds and has undertaken multiple bird surveys in conjunction with Birdlife Australia and its previous entity, the Royal Australian Ornithological Union (RAOU). One of the first citizen science projects in which the Club was involved was the "Great Duck Count"; an RAOU initiative on waterbird locations that was funded by CALM. The first count in which the Club was involved was in 1987 and the members involved included Greg Barratt, Wally Klau, Lois and Bill Powlesland, Chris and Allison Oates and David Pearson.

Over the years the Club has continued to be involved in a range of projects. The Club maintains close ties with the Kalgoorlie-Boulder Urban Landcare Group (KBULG) and supports the Group's local initiatives such as tree planting days. KBULG's administrative office, Eco & Cultural Education Centre, and native plant nursery are all located in Karlkurla Bushland Park. The Park is an area of natural regrowth vegetation on the north-eastern limits of Kalgoorlie-Boulder that was set aside and restored

as part of a dust abatement strategy. It is easily accessible and visited frequently by the general public. The Club has been able to use the facilities for a range of activities. A regular activity is a morning tea held after each seasonal Great Western Woodlands (GWW) bird survey. The Club has held its Christmas end-of-year celebration at the facility for many years which has enabled the Club to have a "bush event" with all the comforts of kitchen and toilet facilities. When celebrating the Goldfields Naturalists' Club's 30th Anniversary in 2017 the Club was able to use KBULG's newly-opened Eco & Cultural Education Centre located next to the native plant nursery.

Birdlife WA has established multiple survey sites within GWW for the Bird Survey Project that was set up in 2012. As part of the project, the Club accepted responsibility for monitoring three 2 ha sites specifically set up in Karlkurla Bushland Park by the GWW Project Officer. As an area of natural regrowth bushland that was readily accessible to the general public, it was an ideal convenient location for survey work and increased the likelihood of participation by the public. The Club monitors the sites each season, inviting the involvement of the public. To support the initiative and encourage participation by the general public, the GWW Project donated 12 binoculars to the Club for the participants.

In the 1990s Suzanne Dennings from the Malleefowl Preservation Group spoke to the Club about the plight of the Malleefowl and gained the interest of the Club in surveying and monitoring those in the Goldfields area. The Club has identified several mounds that are monitored each year. Two sensor cameras were purchased and have been used on some of the less accessible mounds (Fig. 8). These

Figure 8. Malleefowl mound in the Goldfields. Photo: J. Kavanagh.

Figure 9. Active malleefowl mound in the Goldfields. Photo: J. Kavanagh.

cameras have captured evidence of activity by Malleefowl (Fig. 9) as well as the other fauna, including feral species, that visit the mound. The Club continues to monitor mounds with the support of the WA Malleefowl Recovery Group.

The Club has joined the WA Bird Conservation Network (WABCN) set up by Birdlife Western Australia, signing the Memorandum of Understanding on 19 March 2020. Although not a branch of Birdlife, the Club is recognised as an interest group and can participate in meetings. This network is all about sharing knowledge and some resources with the objective of increased bird conservation outcomes in Western Australia.

The Club has also established connections with the Goldfields Environmental Management Group (GMEG) and has been able to run a stall at the last two GEMG Conferences (Fig. 10). The conferences are held in Kalgoorlie but attract delegates from Australia-wide and beyond. This has proved to be mutually beneficial and an opportunity for the Club to keep up to date with environmental management within the mining industry whilst promoting the value of conservation of the local fauna and flora. We anticipate the Club will continue to seek other networking opportunities with like-minded groups including the Esperance Wildflower Society and the Esperance Bird Observers Group.

Figure 10. Goldnats stall at the 2023 GEMG Conference, Kalgoorlie. Photo: J. Kavanagh.

Publications

In addition to the regular Bulletin, the Club has two publications described below. The Club continues to promote and sell both publications at stalls and similar events.

A biological survey of Victoria Rock Nature Reserve

In a report in the Club's September 1988 Bulletin, Andrew Chapman promoted the involvement of amateurs in biological surveys pointing out the significant research and resulting publications that have resulted from volunteer involvement. Andrew was Operations Office at CALM at the time. He pointed out the success of an important biological survey in the Fitzgerald River National Park that was made possible by volunteer support from the Friends of the Fitzgerald River National Park. Andrew proposed that similar projects could be undertaken in the Goldfields starting with a biological survey at Queen Victoria Rock and surrounds.

The first survey work in which the Club was involved was in 1989. Almost 40 people attended the campout over the 1989 Easter weekend and were involved in bird banding, trapping and

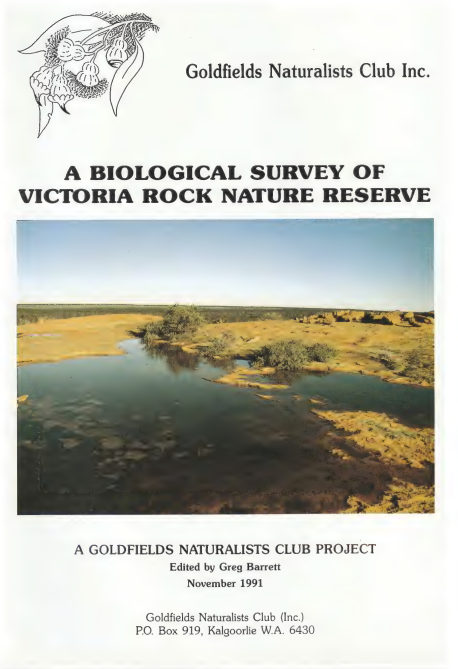


Figure 11. Publication of the Goldfields Naturalists' Club.

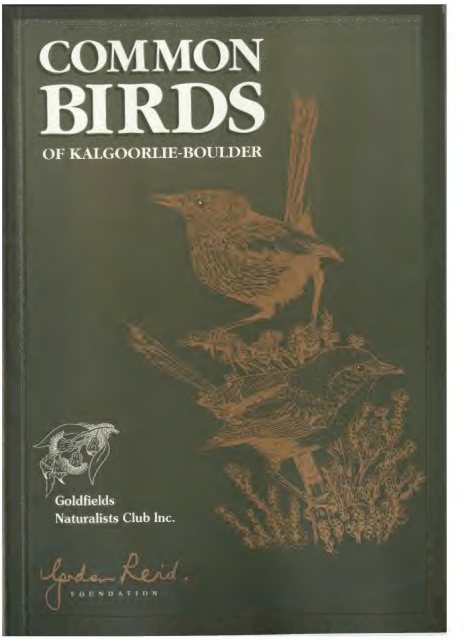


Figure 12. Bird book published by the Goldfields Naturalists' Club.

identifying mammals and reptiles, bat surveys and collecting plant specimens for identification. The project continued over three years and the final report was published in November 1991 (Fig.11). Greg Barrett was the Editor and in the Preface of the publication, he acknowledged Andrew Chapman's key role and the volunteer work provided by the Goldfields Naturalists' Club.

Common birds of Kalgoorlie-Boulder

This book was published in 1995 with the support of funding from the Gordon Reid Foundation (Fig.12). The introduction explains that the book was produced for the people of the Goldfields to help engender a greater appreciation of the local birdlife and that it is relevant beyond the confines of Kalgoorlie-Boulder to other towns and settlements within the WA Goldfields. At the time of the publication, almost all the birds in Kalgoorlie-Boulder were native species; a contrast to many towns and cities in Australia where many of the bird species are introduced. The key authors were Greg Barrett, Andrew Chapman and Michael Blythe, with photographs from Michael Morcombe, Steve Sadler, Jiri Lochman, Peel Howden and Nature Focus.

Thirty years and still going

The Club celebrated its 30th Anniversary with a presentation and

Figure 13. Native flower display at the Goldnats 30th Anniversary. Photo: J. Kavanagh.

Figure 14. Goldnats 30th Anniversary cake decorated by a club member. Photo: J. Kavanagh.

dinner held in October 2017 at the KBULG Eco & Cultural Centre in Karlkurla Bushland Park, Kalgoorlie-Boulder. Members decorated the room with native flora from their own gardens (Fig.13), and one member created a celebratory cake for the event (Fig.14). Three members were awarded Life Membership on this special occasion.

Future role of the Club

Within the Goldfields, the Goldfields Naturalists' Club Inc. is a unique club with a particularly important role. The Club has the ability and responsibility to promote the wonders and value of the natural environment in general and the Western Australia Goldfields in particular. It has responsibilities in contributing to research, increasing the appreciation of our environment, and demonstrating the value of passive activities such as observation, recording, and just "being" in the bush. The passion of the Club's founding members and the diversity of fauna, flora and habitats in the Western Australian Goldfields has provided a solid basis for the continuation of the Club.

Field observations of the Western Ring-tailed Rock Dragon, *Ctenophorus caudicinctus* (Günther, 1875)

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Abstract

An overview is presented of the behaviour and ecology of the common and visually prominent Western Ring-tailed Rock Dragon (*Ctenophorus caudicinctus*), based on field observations. Highlighted is the regional variation in the brightly coloured sexually dimorphic males in the northern part of its distribution (Pilbara) and the reduction in dimorphism in southern populations, including the Goldfields Ring-tailed Rock Dragon (*C. infans*).

Introduction

Storr (1967) recognised one species *Ctenophorus caudicinctus* (Günther) and seven subspecies of this saxicoline ring-tailed dragon lizard. The distinctions were based primarily on male colour (including if black caudal bands encircled the tail) and morphology (including the degree of lateral compression at the base of the tail). The subspecies were:

- *C. c. caudicinctus* found at the time throughout the Pilbara and some offshore islands in Western Australia (WA), from the De Grey River (although today it is known to extend much further northeast from near Anna Plains) south to the Hamersley, Ophthalmia and Robertson Ranges, although again today (*sensu* Storr) it has been observed south into the west Gascoyne to Williambury and the Kenneth Range (pers. obs.), and east to Well 24 on the Canning Stock Route;
- *C. c. graafi* in the central ranges of the eastern interior, southwest almost to Warburton, WA;
- *C. c. infans* in the eastern Murchison goldfields (eastern Goldfields) from northeast of Laverton south to near Kookynie;
- *C. c. macropus* in the Northern Territory (NT) near Oenpelli, although recently known to occur much more widely southeast into Queensland (Qld), and west into WA across the Kimberley;
- *C. c. mensarum* in the Murchison and eastern Murchison goldfields;
- *C. c. rufescens* in the far northwest of South Australia (SA), south to the Birksgate Range and east to Granite Downs;
- *C. c. slateri* in the southern highlands of NT from eastern Macdonnell Ranges southwest to the George Gill Range.

Distribution of the WA populations are shown in Figure 1.

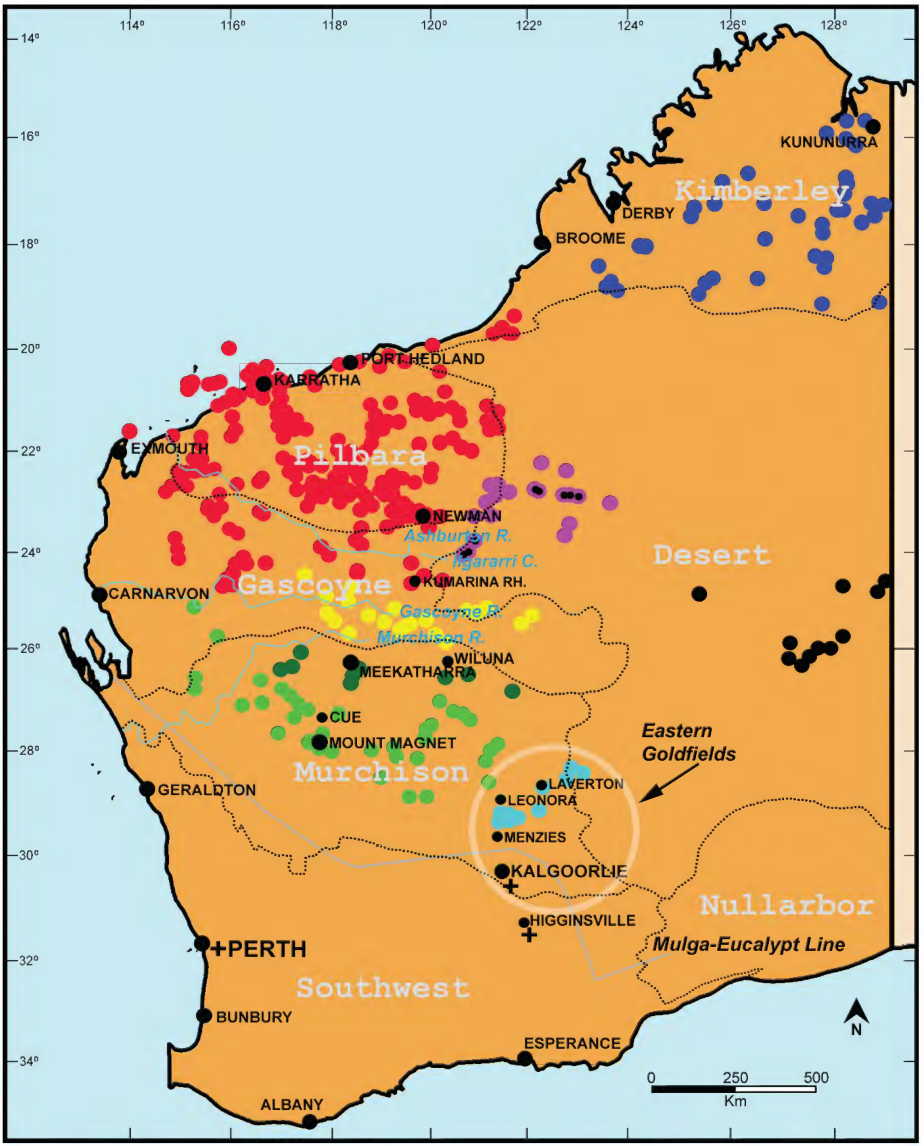

Figure 1. Map of Western Australia showing ring-tailed rock dragon distributions. Dark blue: *Ctenophorus slateri*; red: *C. caudicinctus* nominate population, greater Pilbara; mauve: *C. caudicinctus* eastern Pilbara (EP); mauve with black dot: EP *C. caudicinctus* sequenced by Melville *et al.* (2016); yellow: "*C. caudicinctus-mensarum* intergrade zone" (*sensu* Storr 1967); dark green: "*C. mensarum*" type series; pale green: southern *C. caudicinctus*; black: *C. graafi*; pale blue: *C. infans*; crosses: anomalous records of *C. caudicinctus* suspected of being inadvertently transported to each of the three locations (Perth, Boulder [near Kalgoorlie] and Higginsville).

Storr's 1967 inclusion of *Ctenophorus rufescens* (Stirling and Zietz) from the central ranges in eastern WA as a geographical race of *C. caudicinctus* was based on a lack of well-preserved specimens at the time. He remarked:

> "It is with some diffidence that I treat *rufescens* as a race of *caudicinctus*. For the scanty material is old or poorly preserved and, coming from widely separate localities, is highly variable. My main reasons for doing so are that *rufescens* is clearly a representative of *caudicinctus* and differs from other representatives in only two important respects; the numerous pores and the nostril located well below the sharp rostral ridge; but even these "key characters" are lacking in the single juvenile (SAM 1425)." (p. 52)

Today *C. rufescens* is excluded from the above group based on morphological and phylogenetic evidence and is now the western-most member of the *Ctenophorus decressii* (Duméril & Bibron) species group. The WA ring-tailed dragons, including *C. ornatus* (Gray) and *C. yinnietharra* (Storr), now form the *C. caudicinctus* - *C. ornatus* species group (Melville & Wilson 2019).

Based on both morphological and molecular evidence, Melville *et al.* (2016) recommended that *C. c. caudicinctus*, *C. c graafi* and *C. c. infans* be elevated to full species; *C. c. mensarum* be synonymised with *C. caudicinctus*, and that *C. c. macropus* be synonymised with *C. c. slateri*, elevating the latter to full species. Therefore, a recognition of four species: *C. caudicinctus*, *C. graafi*, *C. infans* and *C. slateri*. They acknowledged, however, that more work is required, particularly regarding *C. slateri* and *C. graafi*, including the relationship between the eastern populations of *C. caudicinctus* and *C. graafi*.

Excluding *C. graafi* and *C. slateri*, I will use Storr's western subspecies' distributions to separate the populations I am referring to from north to south as follows:

- Pilbara: *C. caudicinctus* - north to and including southwestern Kimberley;
- Central southern Gascoyne: "*C. caudicinctus-mensarum* intergrade zone" - immediately to the south of Ashburton River and Ilgararri Creek along latitude 25°S in the Gascoyne River floodplain;
- Northern Murchison: "*mensarum* type series" between latitudes 26°30'S and 26°51'S;
- Central Murchison: southern *C. caudicinctus* south of latitude 27°S.

This will allow the reader familiar with the older subspecies' names to quickly recognise the population in question as the field data and observations are presented, particularly on inter- and intrapopulation variation in adult males' colouration and size.

The Melville *et al.* (2016) study results in four species now occurring in WA with *C. caudicinctus* and *C. infans* endemic. The distribution of *C. caudicinctus* was enlarged with their synonymising of *C. mensarum* with it, such that *C. caudicinctus* now extends over much of the state from the southwest Kimberley in the north-eastern 80-Mile Beach area, south through the Pilbara and Gascoyne and into the greater Murchison and

eastern Goldfields. In this paper I provide photographic examples of representatives from each population showing a north-south clinal change in colour and pattern (Figs. 2–5). Figure 6 also shows a corresponding reduction in size based on largest adult male and female snout-vent length (SVL) measured. Juvenile *C. caudicinctus* from the four respective populations are illustrated in Figure 7. The Pilbara *C. caudicinctus* juveniles look most like those from the "*C. caudicinctus-mensarum* intergrade zone" sharing a variable ground colour and simple body pattern, while the populations further south ("*C. mensarum* type series" and southern *caudicinctus*), including juvenile *C. infans* illustrated in Figure 8, share a

Figure 2. Variation in adult male *Ctenophorus caudicinctus* from the Pilbara. (A) Paraburdoo, (B) 32 km W of Pannawonica, (C) 38 km N of Munjina, (D) 36 km S of Karratha, (E) 35 km SE of Munjina Roadhouse, (F) Ord Ranges E of Pardoo Mine, (G) Karijini National Park, (H) 50 km E of Port Hedland. Photos: B. Bush.

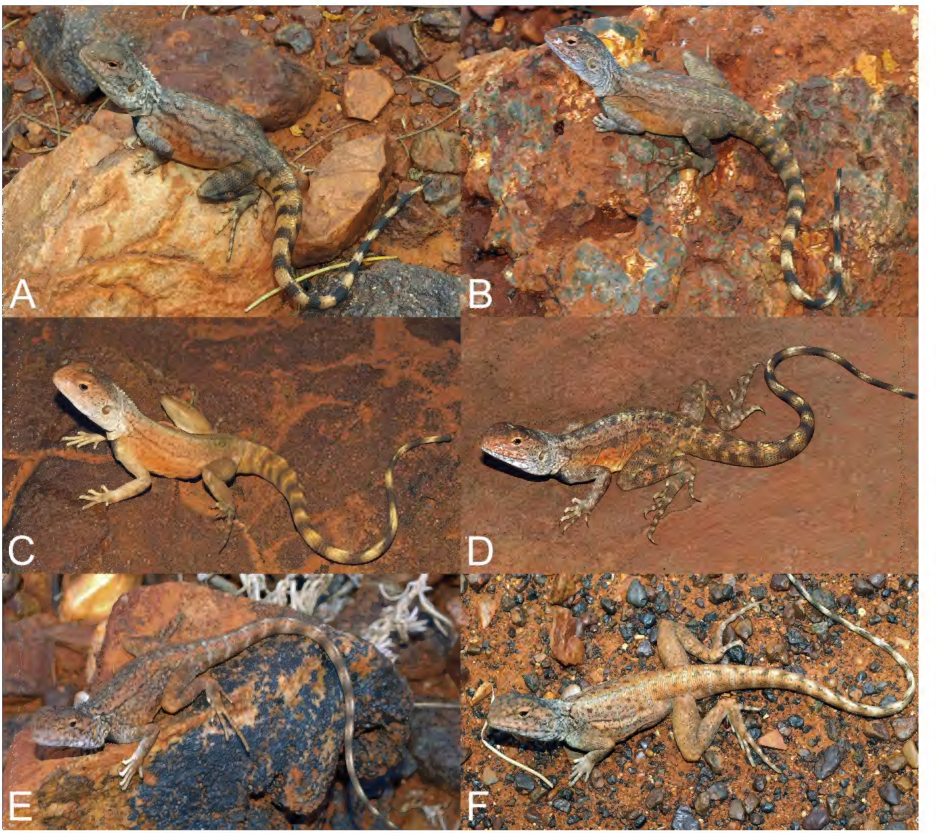

Figure 3. Variation in adult male ring-tailed rock dragons from the "*Ctenophorus caudicinctus-mensarum* intergrade zone" (*sensu* Storr 1967) in the central southern Gascoyne which is along the northern boundary of the "*C. mensarum* type series". The Three Rivers Station access road is 195 km N of Meekatharra and runs WNW of the Great Northern Highway. For a photo of the habitat along this road see Fig. 19C. (A, B) Gascoyne River Middle Branch Bridge area, (C, D, E) Three Rivers Station access road (various locations), (F) Neds Creek Station, 67 km ESE from Great Northern Highway. Photos: B. Bush.

consistent ground colour and uniform, although more complex, body pattern of alternate transverse rows of small white spots and larger black spots. It is my experience that the consistent similarities between members of this cohort cause them to be the most difficult to assign to a population.

With such a conservative group there is little morphological evidence referred to by Melville *et al.* (2016) regarding their taxonomic rearrangement. They do include the following for elevating *C. graafi* to full species "reflecting its morphological difference, isolated distribution and genetic distinctiveness" and with *C. infans* it is based on both morphological and molecular evidence.

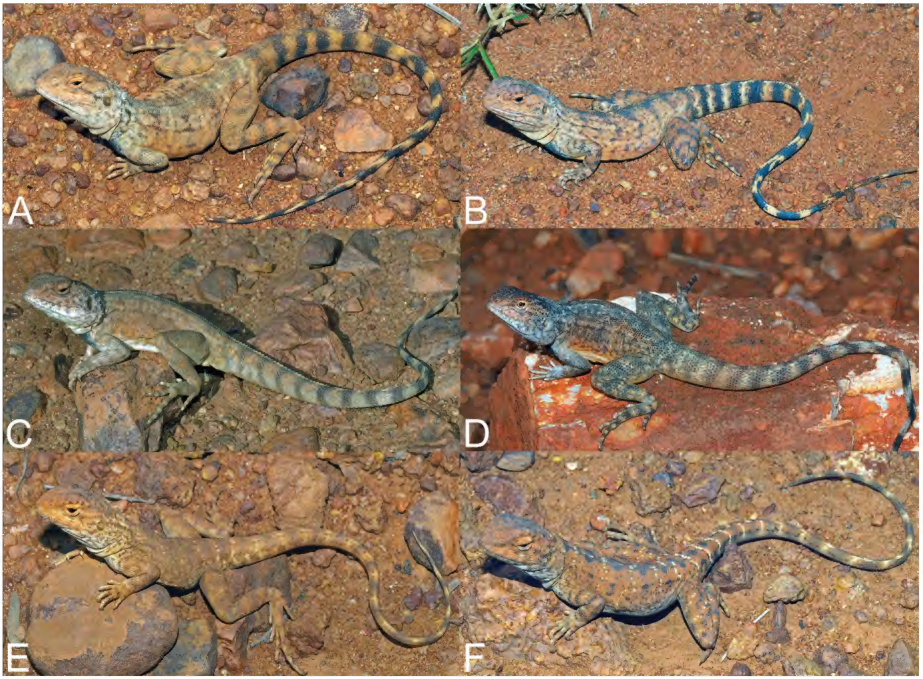

Figure 4. Variation in adult male ring-tailed rock dragons from the location of Storr's 1967 "*Ctenophorus mensarum* type series" in northern Murchison east of Meekatharra. (A), 89 km E, (B) 57 km E, (C) 45 km E, (D) 25 km S of Wiluna, (E) 57 km E, (F) 97 km E. Photos: B. Bush.

Methods

This study is based on field observations from the past 35 years when travelling in WA from the southern goldfields to the tropical Kimberley. During these trips, I visited both well-populated and remote areas to examine and photograph representatives of the local herpetofauna. I have documented 155 ring-tailed rock dragons from the Pilbara, Gascoyne and Murchison: 71 adult, 56 subadult and 28 juvenile individuals.

Visual observations of ring-tailed rock dragons and their behaviour were generally made opportunistically when camped in that respective area, or when purposely visiting particular sites to capture individuals of the local population to allow close examination. The primary technique employed to capture active lizards was noosing, although many individuals were found beneath rocks, cow pads, old vehicle parts and general rubbish or during warm months by head-torch at night when lizards are sleeping in open areas or sheltering beneath cover (Fig. 9).

Examination included measuring SVL and total length with a plastic ruler and noting the sex of subadults and adults. Photographs were taken of the throat, chest, femoral pores, precloacal pores and dorsum. The SVL

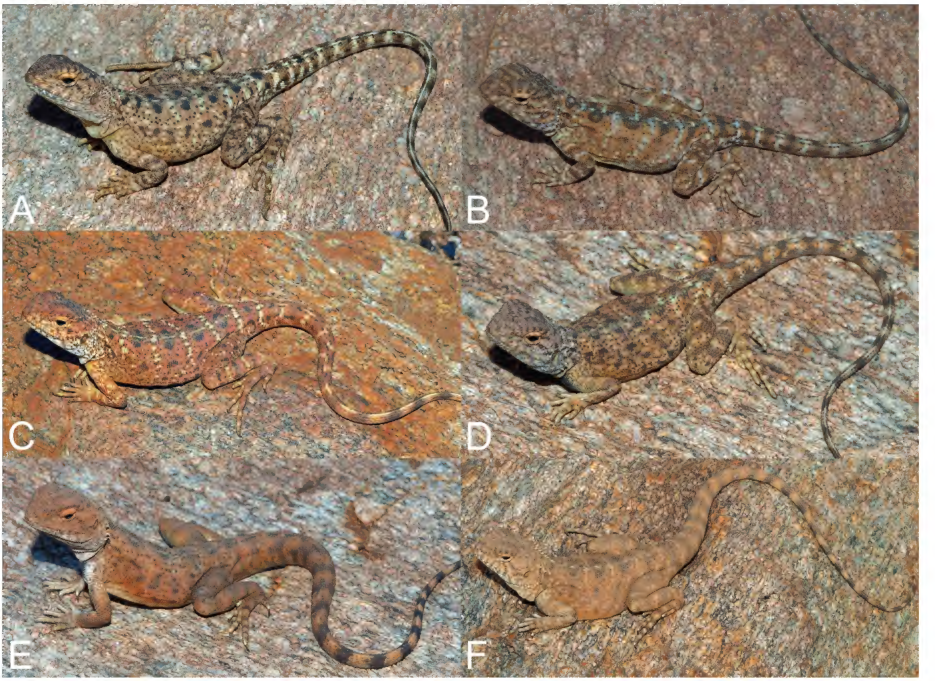

Figure 5. Variation in male southern *Ctenophorus caudicinctus* from the central Murchison. (A) 38 km S of Cue, (B) 45 km N of Mt Magnet, (C) 35 km S of Cue, (D) 38 km S of Cue, (E) 28 km S of Cue, (F) 27 km N of Mt Magnet. Photos: B. Bush.

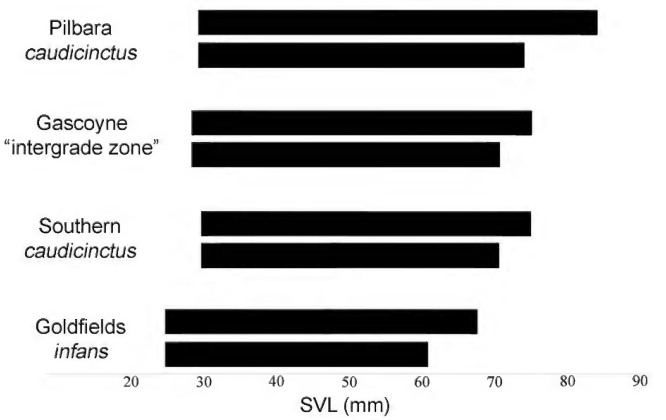

Figure 6. Comparative maximum adult ring-tailed rock dragon size recorded showing a north-south clinal reduction in size: males upper bar and females lower bar. Pilbara *Ctenophorus caudicinctus*, central southern Gascoyne (Storr's "*C. caudicinctus-mensarum* intergrade zone"), central Murchison (southern *C. caudicinctus*) and eastern Goldfields (*C. infans*).

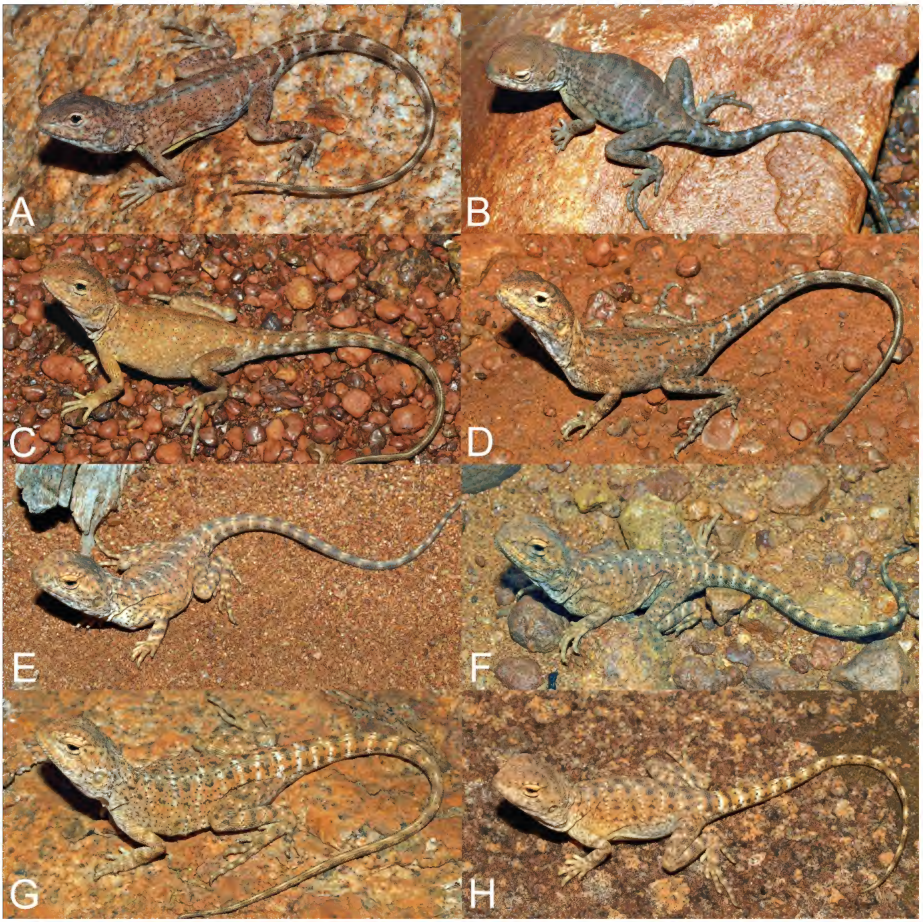

Figure 7. Comparison and variation in juvenile ring-tailed rock dragons. (A, B) Pilbara; (C, D) central southern Gascoyne "*Ctenophorus caudicinctus-mensarum* intergrade zone"; (E, F) northern Murchison (Storr's 1967 "*C. mensarum* type series" location) 45 km and 57 km E of Meekatharra; (G, H) central Murchison (southern *C. caudicinctus*) from near Cue. Photos: B. Bush.

sizes used here to assign individuals to their respective cohort are: ≤39 mm – juvenile (the size below which sex determination is difficult); 40–55 mm – subadult (the size that males commence the development of the chest patch); and ≥56 mm – adult (the size of smallest male southern *C. caudicinctus* with fully developed chest patch; see Fig. 10).

Some aspects of behaviour were also documented by photo and/or video. Video was especially required to document complex head-bobbing sequences that can only be adequately analysed after filming and replaying in slow motion.

All images, montages and photos used here are the work of the author.

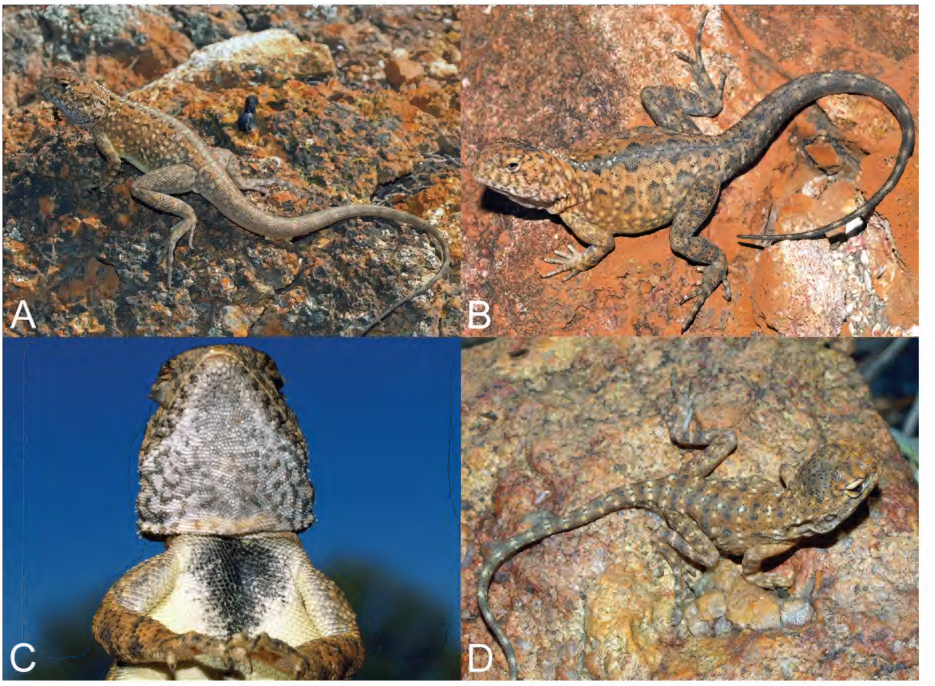

Figure 8. *Ctenophorus infans* is the most southerly occurring ring-tailed rock dragon in WA. (A) adult male, (B) adult female, (C) chest patch of the adult male illustrated here (D) juvenile. Photos: B. Bush.

Field observations and discussion

Behaviour

Basking

Ring-tailed dragons are predominately diurnal sun-loving lizards with recorded body temperatures when active of between 36.5°C and 39°C (Licht *et al*. 1966; Bradshaw & Main 1968). They are frequently observed in the warmer months basking on slightly elevated sites such as small sticks or stones with their dorsum to the sun. As the temperatures rise the basking becomes more intermittent and for shorter periods, with extended periods of foraging on the ground. Foraging involves running short distances, stopping and feeding on several ants in the immediate area before running to another position and repeating the process. Opportunistically much larger arthropod prey (cockroaches, grasshoppers, spiders, etc.) that move into view are also pursued and consumed.

As the temperature rises even further and the ground becomes quite hot (e.g. >50°C), stationary individuals raise the toes on their hind feet so that only the heels contact the ground (Fig. 11; see also Melville & Wilson 2019: p 42). They may also do this with the forefeet but not as frequently. By the early afternoon, they progressively move to more elevated vertical sites

Figure 9. Ring-tailed rock dragons found torpid during cool weather beneath anything laying on the ground, especially dry cow pads, flat rocks and rubbish (adult upper and juvenile lower). Photos: B. Bush.

Figure 10. Fully developed chest patch in small adult male southern *Ctenophorus caudicinctus* of SVL 57 mm from 38 km S of Cue. Photos: B. Bush.

Figure 11. Pilbara *Ctenophorus caudicinctus* male displaying to competitors and females from an elevated position in the Chichester Range, 80 km S of Karratha. Photos: B. Bush.

off the ground to avoid the increasing temperature, particularly the radiated heat rising off the ground as well as the direct rays of the sun, by perching in the shade of large boulders, which they regularly climb as basking sites, termite mounds or tree trunks (Fig. 12). Juveniles are usually on the stone-strewn ground in areas densely vegetated with grasses, especially *Triodia* and are rarely seen off the ground. The subadults and adult females also avoid the more elevated areas and are most abundant around the periphery of the larger outcrops amongst low boulders, they readily climb these as basking sites. These places are also where the grasses are quite dense and overgrowing the boulders, providing the lizards a quick retreat within for protection from predators or when disturbed. The subadults and adults will also make excursions into open areas between isolated tussocks of grass and rely on their speed to escape threats by retreating into the safety of the grass. Although juveniles will occasionally enter open areas also, they tend to defensively freeze with head and body in contact with the ground as if relying on camouflage to avoid predators much in the same way as pebble-mimic dragons (*Tympanocryptis* spp.).

Head bobbing

Towards the end of winter on the Pilbara coast and a little later (early spring) inland adult males are often observed occupying the highest places well above the immediate surroundings. Here they interact with other males similarly positioned and females within their vision by combining a series of one or two controlled head bobs. The head bobbing is followed by a slow

Figure 12. In summer ring-tailed rock dragons perch off the ground during the hottest part of the day on the shaded side of large boulders, termite mounds, tree branches, trunks of trees, etc. Left: gravid females, right: adult males. Photos: B. Bush.

deliberate partial straightening of the forelimbs pushing the forebody upwards and displaying the black chest patch to both competitors and potential mates (Fig. 11).

The above is just one of several head bob sequences observed within a population and performed by all members including juveniles and subadults. It is usually but not always performed after a short run with the least complex being a single head bob with the whole movement not rushed and in even time. It commences in the alert heads-up position, then following a slight elevation in the head position it is lowered before being raised and returned to the alert position, although through this whole action the head is always held angled upward from the ground and does not include any bending of the neck or nodding, rather it is facilitated by keeping the head stationary and raising and lowering the shoulders with a slight straightening and bending of the forelimbs. This may be a single stand-alone sequence, or it may be followed quickly by the same sequence a second time extending the series, although to the naked eye it looks like two rapid head bobs. The most complex and common head bobbing pattern/sequence performed by subadults (although to the naked eye at standard speed appears to be a single head bob followed immediately

by a forebody shiver), however, when slowed down it is a single head bob at the same speed as described above, followed by a series of two or sometimes three extremely rapid head bobs.

Starting from the alert heads-up position, all four simplified sequences begin the same way with a single clear up-down-up (#1 below) and then may be extended as follows.

1 *Up, down, up* at an even time.
2 *Up, down, up…. up, down, up* both series at an even time.
3 *Up, down, up* at even time followed by very rapid *down, up, down, up.*
4 *Up, down, up* at even time followed by very rapid *down, up, down, up, down, up* with the final bob diminishing to marginally more than a shake of the forebody.

Although body re-positioning and limb waving have been observed in *C. slateri* (Ramos & Peters 2017) in the western MacDonnell National Park, they state that this pattern is not present during territorial displays. I have not observed this pattern in Kimberley *C. slateri*, nor in any population of *C. caudicinctus* or *C. infans*.

Nocturnal basking and winter brumation

Individuals, particularly adults, are commonly encountered sleeping at night in exposed places lying flat with eyes closed, head on the ground and body against the warm substrate assumedly to absorb the residual heat. This occurs in many diurnal lizards during summer and especially in the gravid females (pers. obs.). In this latter group, it is believed to facilitate the more rapid development of oviducal eggs by raising body temperature above the cooler ambient. However, this is not the only purpose because the behaviour occurs in both subadults and males, albeit less frequently, the accelerated digestion of food and extending the growth period may be contributing factors to this opportunistic thermoregulation. Nocturnal basking does contribute to lizards being struck by cars at night, especially in the Pilbara where rocky habitats are often dissected by roads. The prevalence of this nocturnal thermoregulatory behaviour is less frequently observed in the south. Bush *et al*. (2007) report briefly on similar behaviour associated with reproduction in tail-squirting geckos (*Strophurus* spp.).

This exposed nocturnal sleeping has also made the lizards an easy target for predators to opportunistically locate individuals. Although snakes can encounter sleeping lizards while foraging, the two species with a predisposition for hunting sleeping dragons are *Suta fasciata* and *S. punctata* (Shine 1983; Bush 2017).

During the winter months, *C. caudicinctus* can be found torpid or brumating (reptile equivalent to mammal hibernation) under objects laying on the ground, particularly easy-to-lift flat rocks and dry cow pads. I suspect the benefit of the latter would be their insulation properties limiting the loss of ground temperature overnight, especially inland where much of its range experiences zero air temperatures at this time of the year. In the southern parts of the range in late autumn, dragons excavate chambers or short burrows in the soil beneath rocks. These may be on low outcrops but more often they are dug around the outcrop's periphery likely owing to the softer soil there.

Comparison of habitat preferences of C. ornatus *and* C. caudicinctus

In areas where both *C. ornatus* and southern *C. caudicinctus* are found, their alternative ecologies and especially habitat preferences separate them quite dramatically. Although both occupy rocky places, *C. ornatus* is a dorsoventrally flattened species that is observed on the large open expanses of granite and uses horizontal crevices as a primary refuge. In contrast, *C. caudicinctus* occurs among the smaller boulders in the stone-strewn intervening areas and when disturbed, seeks refuge among vegetation and in small horizontal or vertical crevices. Figure 13 shows an aggregation of eight *C. ornatus* found torpid on an outcrop beneath an exfoliated rock forming a horizontal crevice in August 2015.

Sexual dimorphism

Storr (1967) reported that males attain a larger maximum SVL than females in all his designated subspecies (males/females, in mm: Pilbara *C. caudicinctus* 89/74; *C. mensarum* = southern *C. caudicinctus* 81/62; *C. infans* 67/60). In his description of the largest subspecies *C. c. macropus* (now *C. slateri*) on page 53, he states the holotype, SAMA R3229 in the South Australian Museum (SAMA) is 89 mm and that the paratype, USNM 128751 in United States National Museum (USNM, Smithsonian Institute) is larger at 101

Figure 13. Aggregation of eight *Ctenophorus ornatus* torpid near Wubin, WA in August 2015. Photos: B. Bush.

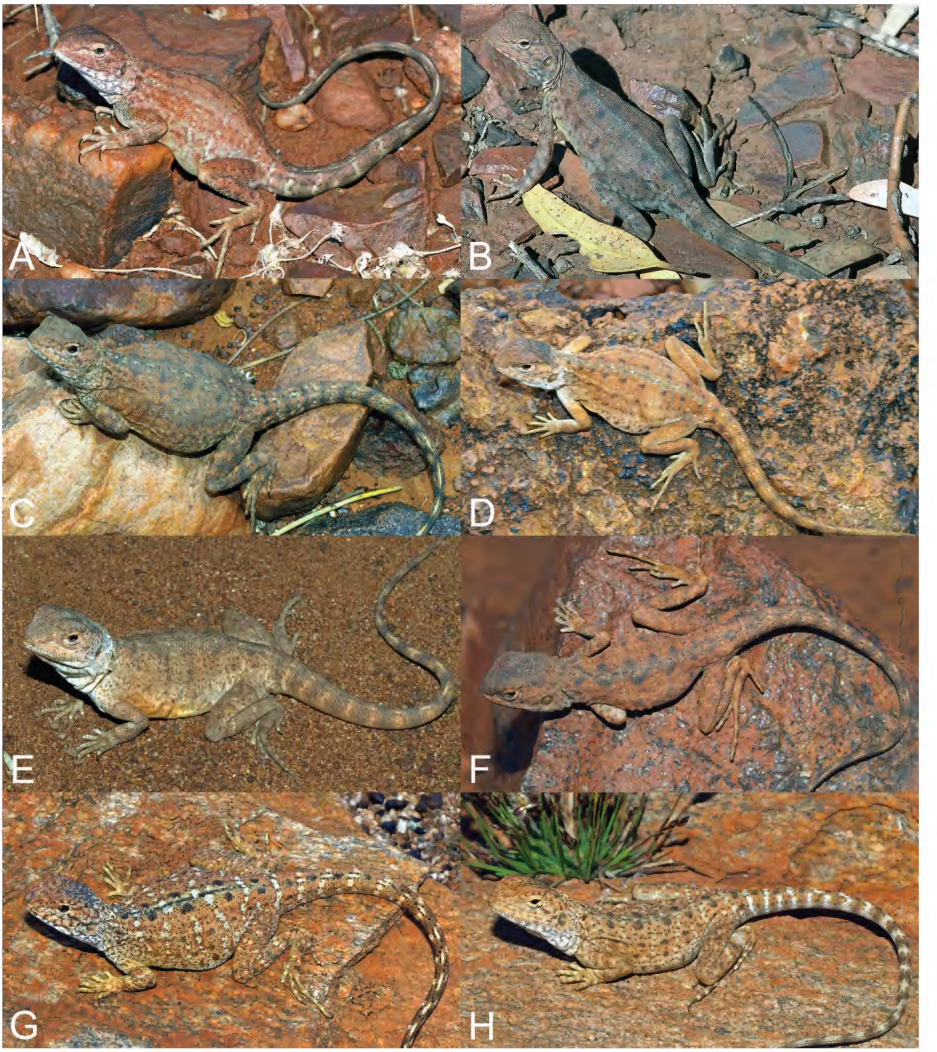

Figure 14. Comparison and variation in adult female ring-tailed rock dragons. (A, B) Pilbara *Ctenophorus caudicinctus*; (C, D) central southern Gascoyne "*C. caudicinctus-mensarum* intergrade zone"; (E, F) northern Murchison ("*C. mensarum* type series" location); (G, H) central Murchison (southern *C. caudicinctus*). Photos: B. Bush.

mm with both being collected on 30 September 1948 near Oenpelli, NT. Apart from this brief mention, Storr does not refer to this large individual again, and I have been unable to find any further reference to it elsewhere.

I also observed sexual size dimorphism, although the largest male *C. caudicinctus* I measured in the field was smaller than Storr's (81 vs. 89) and my largest southern female exceeded his (70 vs. 62). Maximum SVLs (mm)

for *C. caudicinctus* presented in the literature vary and in some of these cases they may have been rounded up, e.g.: 89 (Storr *et al.* 1983); 89 (Greer 1989); 100 (Ehmann 1992); 100 (Bush *et al.* 2007); 100 (Cogger 2014); 90 (Melville & Wilson 2019); and 81 (present study). For a comparison of the regional size and sexual size dimorphism recorded see Figure 6.

As with many Australian agamids (Wilson & Knowles 1988: p. 28; Greer 1989: p. 9; Melville & Wilson 2019: p. 21; pers. obs.), *C. caudicinctus* exhibits some variation in colour and pattern that is evident across all members of any given population, being most pronounced in adult males and to a lesser degree in juveniles, subadults and adult females (Figs. 2–5, 7 & 14). The colour and pattern intensity may also be influenced by an individual lizard's mood, body temperature and season.

Sex can be readily determined in adults and subadults but not in juveniles ≤40 mm. It is from this size that the black chest patch is seen in adult males but absent in females (Figs. 15A vs. 15B) begins to develop as indicated by a darkening of the chest in subadult males. The progressive development of the patch relative to size is shown in Figure 16 (middle column). The chest patch may temporarily lose intensity or entirely vanish in males found at night during the warmer months sleeping under cover or when brumating during winter but returns quickly when the individual is disturbed or when it becomes active.

Interscalar femoral and precloacal pores occur in juvenile, immature and adult members of both sexes, but contribute little to identifying the sex of an individual. Even though there are marginally more pores in males than females: 30.6 (24–40; N 35) versus 27 (20–36; N 24), the substantial overlap in numbers between the sexes renders the counts of little relevance for sexing individuals. In older adult males, which already have the black chest developing, these pores become far more active than in juveniles, subadults and females, with this activity increasing their comparative diameter. The secretions can be long conical protrusions and therefore also dimorphic, but usually only in larger males. Figure 15E shows these secretions and allows a comparison of the pores in an adult male (SVL 72 mm) and gravid female (SVL 67 mm) found on the same day in January 2017 near Middle Branch Bridge, Gascoyne River (25°11'02"S, 119°19'46"E) under an old car door.

When examining the base of the tail immediately following the cloaca in Figure 15C and all individuals illustrated in Figure 16 (right column) there is an external indication of male hemipenes in the form of a swelling to either side of the midline that extends laterally and is deeply indented posteriorly at its centre by a depression. Note that this is absent in the sexually mature female illustrated in Figure 15D with the posterior margin being straight. However, it is not always as obvious, so I am hesitant to place too much reliance on it in determining the sex of small or poorly marked individuals in the field.

The size of the upper and lower canine teeth may be another sexually dimorphic indicator in adults as shown in Figure 17. Those in a male of SVL 76 mm photographed in November are much larger than in a comparable-sized gravid female of SVL 74 mm photographed in mid-March. The

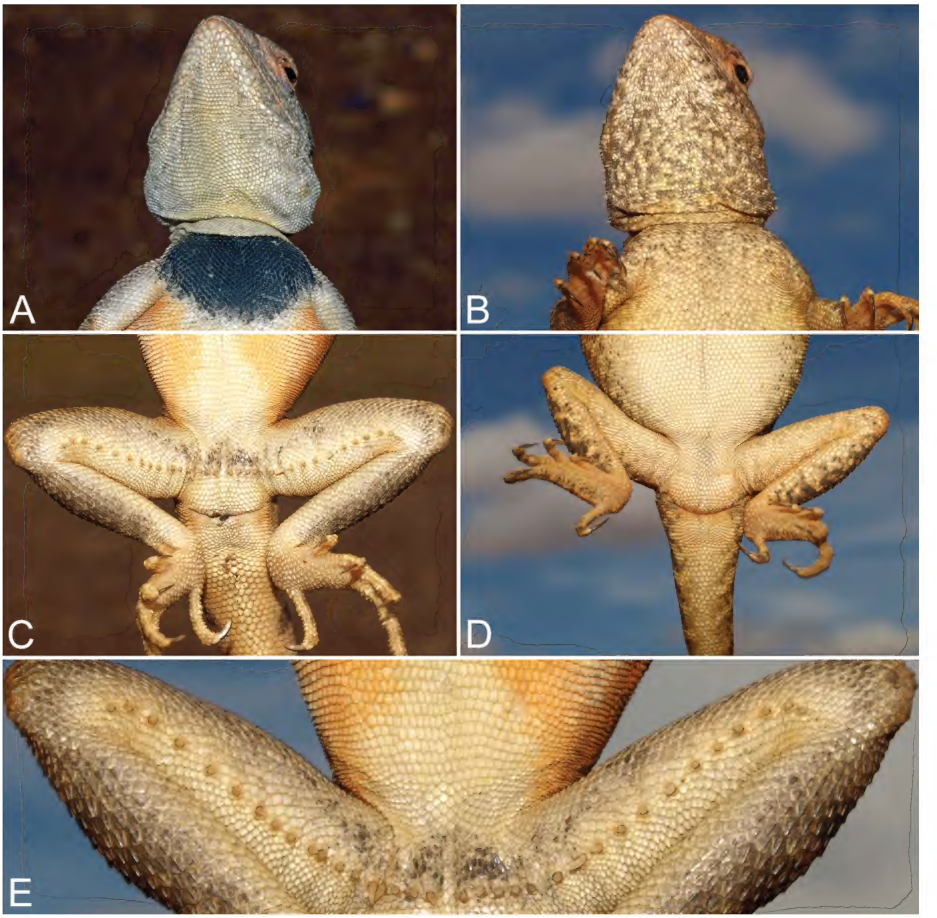

Figure 15. Ring-tailed rock dragons from central southern Gascoyne showing the obvious sexual dimorphism in colour and development of precloacal and femoral pores. (A,C) male; (B, D) female; (E) a close up of the conical protrusions from active pores in male. Photos: B. Bush.

growth of the canines in adult males may be seasonal preceding reproductive behaviour and assist the males in restraining females during mating.

Geographical colour and pattern variation in adult males

Colour is significant in determining polymorphic and monomorphic agamid lizard lineages (Dong *et al.* 2021) and is used to differentiate species in the saxicoline *C. decresii* group (Houston 1974; Gibbons & Lillywhite 1981). The importance of male colouration in species diagnosis in that group has become even clearer (Johnston 1992; McLean *et al.* 2013) as has camouflage and interactions between individual lizards (McLean

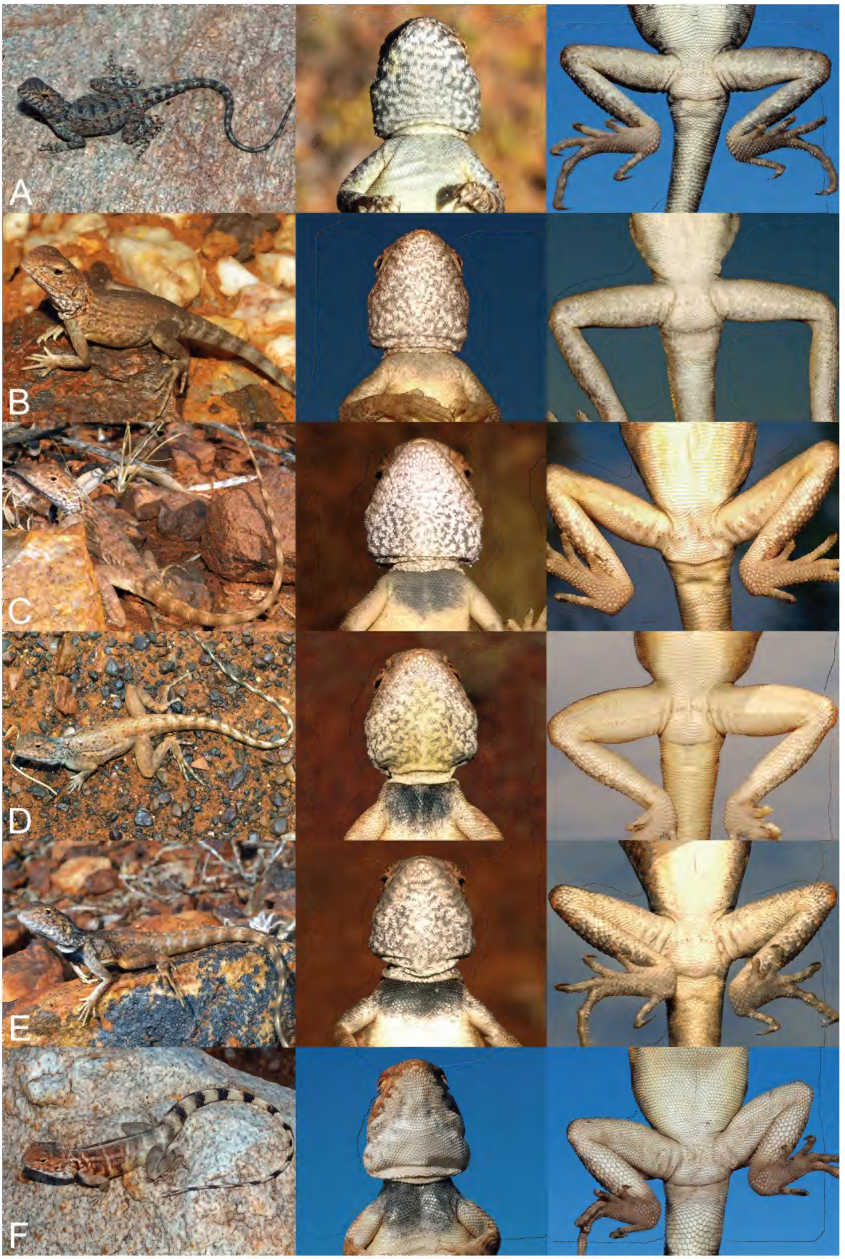

Figure 16. Male ring-tailed rock dragons showing the progressive development of black chest patch relative to size (SVL mm) and the lack of this development in the femoral and precloacal pores until they become active in older males. (A 42, B 47, C 54, D 60, E 68, F 81). Photos: B. Bush.

et al. 2014, 2015). In contrast, male *C. caudicinctus* show both inter and intrapopulation variation. A sample of Pilbara adult male *C. caudicinctus* is illustrated in Figure 2. Here, the ground colour is variable, and this is especially so in Figure 2E from near Munjina where the ground colour is darker in this part of the Hamersley Range. This is also seen in individuals of the local military dragon (*C. isolepis*; unpublished data). However, there are three constant characteristics that the Pilbara ring-tailed rock dragons tend to share: they all possess a black chest patch, black bands along the length of the tail and two wavy dark brown longitudinal lines on the flanks.

Moving south into the central southern Gascoyne (Storr's 1967 intergrade zone), the black chest patch and the two wavy dark longitudinal lateral lines are still consistent characters retained in adult males, but the black tail bands (consistent in Pilbara *C. caudicinctus*) become less defined (Fig. 3). Of the six male individuals illustrated, only A and B retain these, while in C and D they have significantly faded and in D are starting to fragment, while in E and F only remnants remain. Illustrated in Figure 4 from further south in the northern Murchison where Storr's "*C. mensarum* type series" originated, there is a similar reduction of the tail bands and in the consistency of the two wavy lateral lines, with these absent in E and F.

Storr (1967) referred to intergrading between typical (nominate) *C. caudicinctus* and "*C. mensarum*" and commented that if a boundary can be defined between them, it would probably be found along the Ashburton River, upper Gascoyne and Ilgararri Creek drainages (see Fig. 1). The central southern Gascoyne population, as

Figure 17. Larger canine teeth in a male ring-tailed rock dragon (SVL 76 mm), 38k N of Munjina (left photo), compared with that of a gravid female (SVL 74 mm), near Tom Price (right photo). Photos: B. Bush.

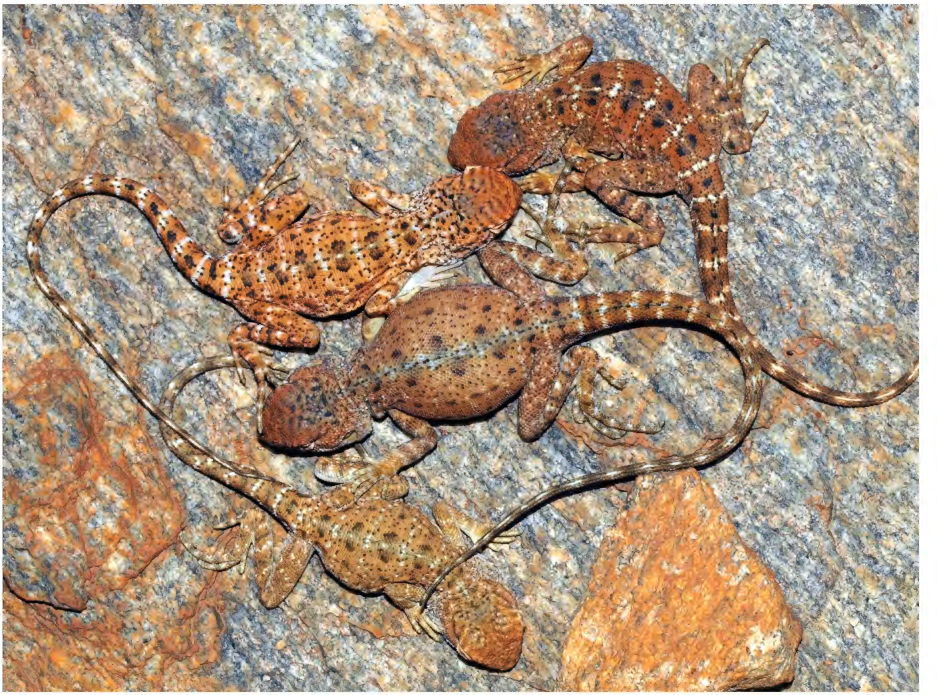

Figure 18. Variation in southern *Ctenophorus caudicinctus* from one rock outcrop 40 km N Mount Magnet. Photo: B. Bush.

presented in Figure 3 are all recorded along or just to the south of the east-west midline of Storr's hypothetical boundary which he suggested might be between latitudes 24° and 26°S. I have found the transition from Pilbara *C. caudicinctus* to southern *C. caudicinctus,* hence the intergrade zone, to be generally the same as Storr's interpretation with adult males along latitude 25°S visually the most different to both the Pilbara and the northern Murchison "*C. mensarum* type series" populations. In 1967, Storr had little material to work with apart from juveniles and subadults, so the southern boundary (along latitude 26°S) of this intergrade zone may also have comprised some of his "*C. mensarum*" at the time. However, south of both this east-west zone and the northern Murchison "*C. mensarum* type series" band, the morphological changes are more pronounced, with a complete loss of the black anterior tail bands being replaced with marginally darker bands in some, but in most these are reduced to dark spots over areas of ground colour between narrow white bands and a merging in body colour and pattern between males (Fig. 5) and females (Figs. 14G & H). This has resulted in the sexual colour dimorphism dorsally obvious further north to be almost non-existent in the southern *C. caudicinctus* population where it is morphologically intermediate between

Pilbara *C. caudicinctus* and *C. infans*. Compare *C. caudicinctus* males in Figure 2 and females in Figures 14A & B with southern *C. caudicinctus* males (Fig. 5), females (Figs. 14G & H) and assorted individuals from the one location in Figure 18. Also, the central southern Gascoyne and northern Murchison (type series) form is observed equally abundant on sparse stone-strewn heavy loam substrates (Fig. 19C) and on stony hills (Fig. 19D), although southern *C. caudicinctus* appear far more habitat-specific being almost wholly restricted to large, low granite outcrops (Figs. 19E & F) and *C. infans* to more elevated rocky outcrops (Figs. 19G & H).

Seasonal fluctuation in population demographics and longevity

The seasonal demographics follow the usual pattern (Shine 1989; Bush 1992; Melville & Wilson 2019: p 47) seen in the southern hemisphere in many oviparous reptiles that lay multiple clutches during a breeding season (Fig. 20). That is, early spring mating, late spring and early summer egg deposition, late summer and early autumn hatching with juveniles abundant throughout autumn, peaking in the late part of that season (May) and declining through winter. Subadults are abundant in late autumn through early winter and peak again in late spring becoming adults at this time, and adults occur throughout the year. The extended period of occurrence observed here in juveniles and subadults is probably a result of both the extension of the breeding season caused by multiple-clutching and the additional influence of the graduated temperature over the study area (where on the coast minimum temperatures are higher than inland areas where extremely low autumn and winter temperatures can often be <0°C). Exposure to these low temperatures would retard lizard growth and therefore extend the seasonal occurrence of these two cohorts within the wider population.

In the Pilbara south of Karratha through the Gascoyne to north of the Ashburton River, adult females were recorded with well-developed palpable eggs in December (2), January (5), February (8) and March (11). These heavily gravid individuals were most often found inactive at night with their ventral surfaces pressed against the warm substrate. The SVL in this gravid series was 61–70 mm. Clutch sizes of 4–8 have been recorded (Bradshaw 1981; Pianka 1986; present study).

Based on examination of specimens, Storr (1967) suggested Pilbara *C. caudicinctus* might be short-lived, breeding at about nine months of age and dying a few months later. Juveniles hatching between March and June and acquiring adult characteristics when about 55 mm SVL (commencing at 40 mm in males; present study) between June and September (but as late as November; present study) and dying after 12 months. Storr categorised individuals as adults when SVL in males was 76–89 mm, females 57–74 mm; as subadults in males 56–73 mm, females >58 mm and as juveniles (unsexed) 23–55 mm. During this study, the size ranges of the three arbitrary age classifications are adult >59 mm, subadult 40–59 mm and juvenile <40 mm. Adult males and females were found throughout the year, so I suspect there is an overlap with late-maturing adults and maybe other mature individuals living for two years or longer.

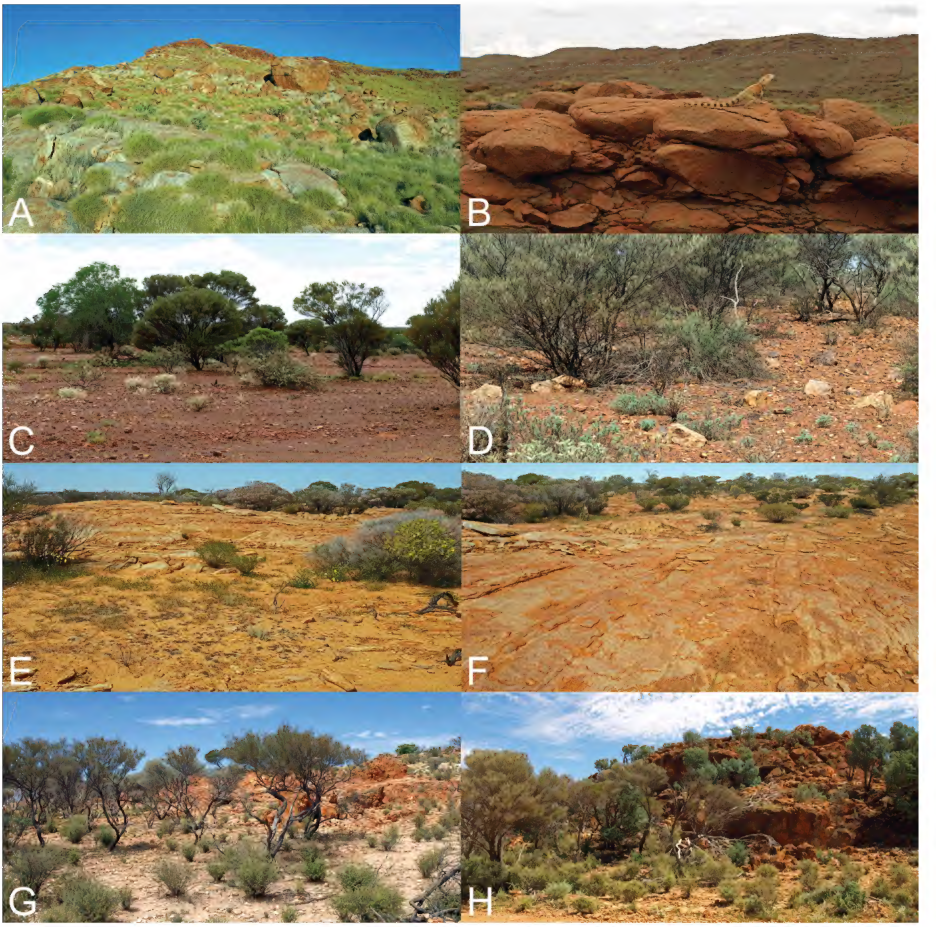

Figure 19. A range of habitats that ring-tailed rock dragons occur in from rocky outcrops and stone-strewn flats to gravelly and clay substrates with only sparsely strewn stones. (A, B) Pilbara (*Ctenophorus caudicinctus*); (C, D) central southern Gascoyne and northern Murchison respectively ("*caudicinctus-mensarum* intergrade zone" and "*mensarum* type series"); (E, F) central Murchison (southern *C. caudicinctus*); (G, H) WA Goldfields, east of Laverton (*C. infans*). (A) Spinifex and stony hill east of Port Hedland, (B) layered granite hills, Chichester Range, (C) stone-strewn flat that is typical of much of the habitat in the Gascoyne, Middle Branch Bridge, Gascoyne River, (D) low stone-strewn hill west of Wiluna, (E) low granite outcrop near Cue, (F) granite flat near Mount Magnet, (G) rocky outcrop east of Laverton, (H) rocky outcrop east of Laverton. Photos: B. Bush.

Observations of captive-bred *C. infans* suggest that under optimum conditions it can live into its sixth year and produce multiple clutches (2–5 in a season) of 5–7 eggs as recorded by Australian dragon specialist keeper, Mark Hawker of Narooma, NSW (pers. comm.; July 2021) he said that he got his first group comprising six hatchlings in

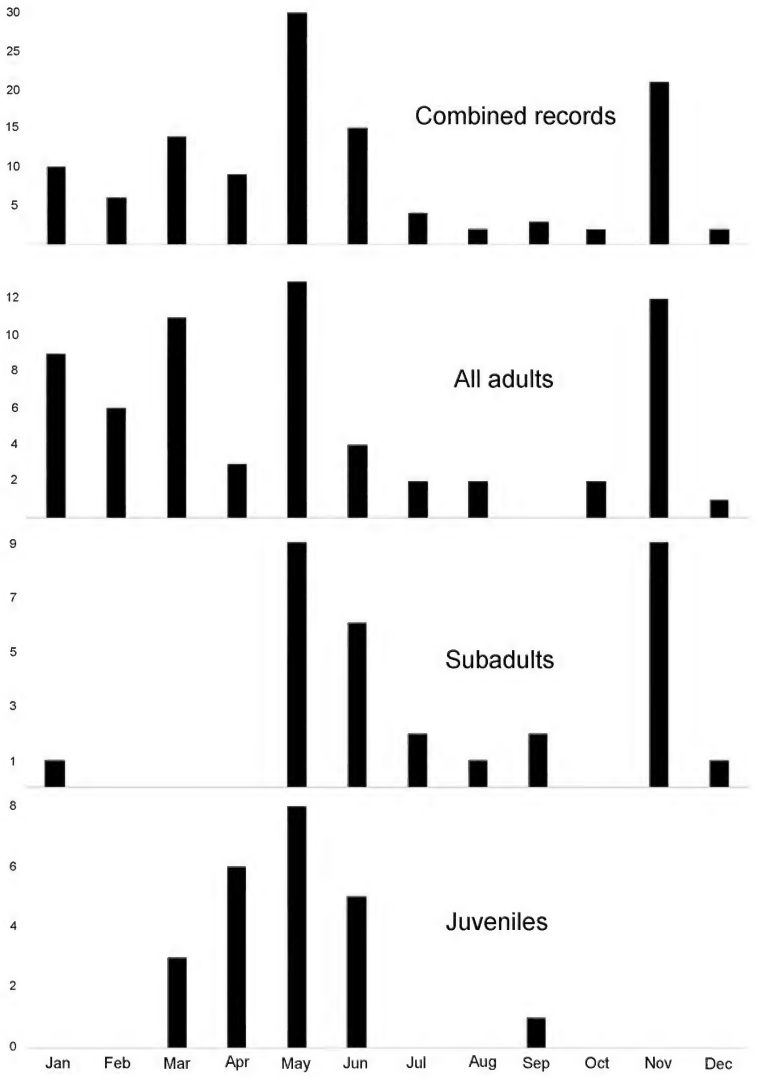

Figure 20. Monthly frequency of ring-tailed rock dragons in all cohorts examined during this study.

April 2016 and captive individuals were still breeding after two years of age under good conditions. At the time of our correspondence, he had individuals that were four years old that produced two clutches of eggs in the most recent summer and one male individual (the last surviving from the original six acquired in April 2016) that was at the time showing signs of age-related physical deterioration (preceding death) in the early part of

its sixth year. However, he relayed that in his experience *C. infans* appears to be the most robust of the ring-tailed rock dragons he has kept in captivity to date, which have included *C. ornatus* and *C. slateri*.

In July, *C. caudicinctus* in the coastal and near-coastal Pilbara are active from the mid-morning until the late afternoon when daytime temperatures have risen to 23°C and continue rising to about 30°C for most of the day, but inland at a site 70 km north of Newman there is similarly no activity in the morning when temperatures are below 22°C until early afternoon and then only minimal activity as the temperature rises to a maximum marginally exceeding 23°C. The higher Pilbara coastal and near coastal temperatures may result in extended activity periods both during the day and for much more of the year, and this would possibly shorten longevity compared with the inland and southern populations, which spend much more time brumating with this contributing to a greater longevity.

Fluctuations in seasonal conditions in the wild would probably influence longevity, especially the sudden and dramatic impact of fires and floods and the reduction in food that may be the immediate aftermath of these events. I hypothesise a life span of two to four years would be typical in all members of the *C. caudicinctus* group.

Anomalous specimens

The southerly distribution of ring-tailed rock dragons in the eastern Murchison is generally well to the north and east of the mulga-eucalypt line, with museum records suggesting the southern boundary is 35 km northeast of Menzies in the central northeastern goldfields (*C. infans*) and northwest of Leonora (*C. caudicinctus*), then just to the northwest of Lake Noondie near Yuinmery Station homestead, Mount Magnet, west to Tardie and Mileura Stations in the Midwest region; and east to Mt Fisher on Yelma Station in the Wiluna Shire. However, there are three records from much further south, deep into the eucalypt-dominated Western Woodlands and Perth metropolitan areas identified as *C. caudicinctus* that are best-considered anomalies and ignored with respect to the group's WA distribution until further specimens are identified from these respective locations. The specimens are NMV R887 with little associated data attached but supposedly collected in South Perth and held in Museums Victoria, Melbourne; AM R3081 from Boulder collected by W. Campbell in December 1900 and held in Australian Museum, Sydney; and WAM R126476 from near Lake Cowan, 7 km southeast of Higginsville collected by Biota in January 1996 and held in the Western Australian Museum. This is 293 km south of the most southerly location previously known for ring-tailed rock dragons and 230 km south of the mulga-eucalypt line. The inadvertent transport and possible introduction of reptiles from the mulga belt north of Goongarrie to the mallee-dominated Esperance sandplain has been previously documented by Bush (1987).

In southern WA, disregarding the poorly documented Perth record, where both inland anomalous specimens were found, it has been prospected and mined since 1893 with much movement of both people and their personal and commercial equipment throughout these regions. Both isolated records may

Figure 21. Ring-tailed rock dragon (WAM R126476) - SVL of 57 mm, collected on 14 January 1996 from 7 km southeast of Higginsville in 31°50'S 121°43'E and believed by the author to be a southern *Ctenophorus caudicinctus* inadvertently introduced from possibly the Mt Magnet area. Photo: B. Bush.

not represent naturally occurring populations, but rather individual records of inadvertently transported dragons introduced to these places from north of the mulga-eucalypt line.

A comparison of adult *C. infans* (Figs. 8A & B) with the Higginsville specimen (Fig. 21) indicates that it is not *C. infans*. When compared with the southern *C. caudicinctus* individuals depicted in Figure 18, it is almost identical and adds support to the argument that the Higginsville individual was inadvertently introduced. In addition, *C. infans* is the most southerly species of the group, thus potentially forming a barrier excluding *C. caudicinctus* from naturally dispersing south to the Higginsville area.

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Systematic methods for additions and exclusions from the naturalised flora of Western Australia

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Abstract

Western Australia should adopt international standards for the invasion flow line to add species as naturalised. Only adequately documented herbarium collections, preferably with supporting documentation (in the form of observations on the numbers of plants, area of occupancy, mode of reproduction, etc.) should be added as naturalised; others should be treated as casual aliens. In databases, collections and subsequently taxa should be annotated with one of the following categories: alien cultivated; casual alien; naturalised alien or invasive alien. A separate category is already in use for species native to Western Australia that behave as invasive weeds outside their native range.

Deletion of alien taxa from a census or checklist should also be formalised under three criteria: presumed extirpated (no records for over 50 years); presumed never naturalised (no evidence of collections from a naturalised population) and presumed eradicated (targeted campaigns to eradicate and no records for 20 years). In this paper, 22 species are proposed to be deleted as naturalised in Western Australia under this system.

Introduction

The naturalised (i.e. weed) flora of an area is in a constant state of flux, with species naturalising, some on the verge of becoming naturalised, others ceasing to exist in the wild either through targeted eradication or other causes, and finally, those that invade many areas/habitats and become a permanent part of the flora that will always be present despite efforts to eradicate them.

The purpose of this paper is to document how taxa should be added or removed from the Western Australian Plant Census as being naturalised in Western Australia (WA). A second aim is to set up a method

of annotating taxon records as to their status as alien taxa in the flora treatments, census and checklists (e.g. *Flora of Australia*, Florabase and the Australian Plant Census [APC]).

Adding species as naturalised

There are many systems for adding naturalised taxa to flora treatments and checklists (e.g. Australian Plant Census; Webb *et al*. 1988; Nesom 2000; Hosking *et al*. 2007), and they appear to have been variously applied to lists of Australian taxa. Collectors, herbaria, taxonomists and flora writers tend to focus on what has been recorded growing in a non-cultivated state, usually over the period from introduction to naturalisation, rather than the invasion of natural ecosystems. Ecologists focus on the invasive nature of naturalised species, both for theoretical and practical issues. The increased usage of online data searches by ecologists interested in species invasion of natural ecosystems, without a full understanding of the predominant focus of these databases, has led to errors and confusion about what are referred to as naturalised/invasive taxa in checklists, floras and online databases.

A recent example of the potential problems caused by analysing general searches of taxon names databases can be found in Arianoutsou *et al*. (2013). The authors listed 791 species as naturalised in Mediterranean WA (nearly the entire naturalised flora of the area). The compiled database was then transformed in the paper into 'environmental weeds' (i.e. were present and spreading in the natural bushland), giving southwestern Australia the most invaded Mediterranean biome in the world. However, checking published sources would have revealed that of the 1233 vascular plant species recorded as naturalised in WA only 677 taxa (55%) have been recorded in highly disturbed to disturbed bushland at least once, let alone invasive in natural bushland for the entire state. The much smaller southwest has a similar proportion of weeds of native bushland, about 375 of over 800 naturalised species (Keighery & Longman 2004). This is not to say that invasive species are less serious here compared to other Mediterranean biomes: they are different in type and origin, rather than more numerous.

The naturalisation/invasion barriers flow line (Richardson *et al.* 2000)

To become naturalised, introduced plants pass through several stages. Five stages are distinguished in the flow line.

1 **Introduction (and/or cultivation)**: Strictly speaking, these plants are the province of horticultural floras (e.g. Spencer 1995, 1997, 2002a, 2002b, 2005; Walters *et al*. 1984–1989), monographs and taxonomic studies. Some Australian herbaria, such as the National Herbarium of Victoria (MEL), have large collections of this material and together with flora treatments, they are valuable in determining the identity of many naturalised taxa. However, they are generally not considered in floras or checklists, because they are cultivated and do not appear in most taxon names databases.

   Richardson *et al.* (2000) list 'introduction' as meaning "the plant … has been transported by humans across a major geographic

barrier" and populations of adult plants are established. While this is a useful definition, there are some unique issues with it for tropical Australia. For a group of mainly tropical Australian plants, it can be difficult to determine which were introduced either via long-distance dispersal or perhaps by humans before European settlement (Kloot 1987; Webber & Scott 2012; Keighery 2013). Several of these are now major weeds, e.g. *Passiflora foetida* L. To overcome the problem of secondary spread, Pyšek *et al*. (2004) define such species as alien, i.e. "plant taxa in a given area … whose presence there is due to intentional or unintentional human involvement, or which have arrived there without the help of people from an area in which they are alien" (p. 135). This definition conforms with Bean (2007) and classifies *P. foetida* L. as an exotic alien.

2 **Persisting**: Usually cultivated perennial plants that remain in place without human assistance, often after the site has returned to a more natural state. These plants generally are not reproducing, or at least not spreading beyond the original planting (Nesom 2000). Hosking *et al*. (2007) list such species as 'naturalising', while many floras, e.g. Webb *et al*. (1988), list them in annotated summaries or in unannotated lists. An excellent example in WA is the garden Bouganvillea, *Bougainvillea glabra* Choisy, in the Pilbara. We recommend well-annotated (noting numbers of plants, rate of spread, previous use of location etc.) collections of such species, since they may, as shown by Esler (1987), be the earliest record of the naturalisation/invasion process.

A lack of documentation, especially collections of such records, causes uncertainty for future researchers. For example, Ghafoor (2015) in his treatment of *Vernonia* for the *Flora of Australia* lists one naturalised species (*V. junghuhniana* J. Kost.) but notes that *V. altissima* Nutt., *V. arkansana* DC., *V. glabra* (Steetz) Oliv. & Hiern, *V. mespilifolia* Less. and *V. pedunculata* (Pers.) DC. have all been listed as introduced/naturalised to Australia in Willis (1970) and Randall (2007). However, he was unable to locate any supporting documentation or herbarium specimens to confirm these records, thus their identity and naturalisation status remains unknown.

3 **Waifs or casuals**: Terms used mainly in European and North American floras for plants of non-native species growing outside of cultivation but not maintaining a viable population for more than one or a few seasons (e.g. tomatoes [*Solanum lycopersicum* L.] in sewerage sludge pits). Several of these species, *Brassica x napus* L. (canola), *Triticum aestivum* L. (wheat) and *Secale cereale* L. (cereal rye), are maintained by repeated seed fall from harvesting and transportation activities along roads. The latter two are proposed to be deleted as naturalised species for WA in this paper. However, they are so commonly seen that it may be preferred to treat them as casual aliens.

Brassica x napus L. (canola) is often treated as belonging to this

category but is a difficult case. While most older records are either obviously cultivated: Donnybrook, 1955 (PERTH 03243054); Esperance, 1974, (PERTH 03245691); University of WA, 1973 (PERTH 03242765); Badgingarra Research Station, 1976 (PERTH 04400240) and Swan Cottage Garden, 1992 (PERTH 04102797). More recently annotated collections are from spillages along road verges mirroring increasing cultivation as a crop in the agricultural zone: Kings Park, 1979 (PERTH 03243133); Cape Naturaliste (PERTH 03242749); North Beach, 1986 (PERTH 05941369); Belmont, 1995 (PERTH 04227735); Waroona, 1995 (PERTH 04227999); Kensington, 1995 (PERTH 04232542); Hyden, 1995 (PERTH 04312260); Dowerin, 1996 (PERTH 04605756); Brookton, 1996 (PERTH 04677811); Yealering, 1996 (PERTH 04677838); Wundowie, 1996 (PERTH 04468902); Karratha, 1997 (PERTH 04982452); Kamballup, 1997 (PERTH 05739861) and Kulin, 1998 (PERTH 05399017). A few recent records are from fodder usage: Home Creek, Sturt Station, 2005 (PERTH 07852975 & 07860455). However, two recent collections from the edges of wetlands in regional parks in Perth – Lake Coogee, 2006 (PERTH 07852223) and Lake Richmond, 2007 (PERTH 08273731) –suggest that this species may be establishing self-perpetuating populations. Observations on these populations are needed.

4 Both Richardson *et al*. (2000) and Pyšek *et al*. (2004) combine taxa in stages 2 and 3 as 'casual' alien plants.

5 **Colonisation/naturalisation**: Used by Richardson *et al*. (2000) to denote plants in founding populations which increase to form a colony that is self-perpetuating without direct intervention by humans. This definition corresponds to the classical definition of naturalised. Floras and checklists may list single or small populations as 'sparingly naturalised', for example in the APC.

Frequently a timeframe of establishment/presence (25 years) or a distance measure for vegetatively reproducing species is added (Tutin *et al*. 1964). Pyšek *et al*. (2004) define naturalisation as "alien plants that sustain self-replacing populations for at least 10 years without direct intervention by people (or despite human intervention) by recruitment from seed or ramets (tillers, tubers, bulbs, fragments etc.) capable of independent growth" (p. 137). An example is given in Box 1.

6 **Naturalisation/invasion**: Richardson *et al*. (2000) define this as "the species establishes new self-perpetuating populations, undergoes widespread dispersal and becomes incorporated with the resident flora" (p. 101). For ecologists, this is the most important part of naturalisation as it is the 'invasive' phase, and many species never reach this criterion. In Australia, taxa invading natural ecosystems are referred to as "Environmental weeds" (Keighery & Longman 2004) to distinguish them from weeds affecting horticulture and agriculture. A

BOX 1: Example of a sparingly naturalised species

Strelitzia nicolai Regel & Körn. (giant bird of paradise). Photo: Greg Keighery.

Three mature clumps of this species were located in 2016 in Charterhouse Swamp, Eaton, north of Bunbury (PERTH 09095438). They had flowered and set copious seed, and scattered seedlings were present at the site. From the size of the plants, it was obvious that the species had been present at the site for more than 10 years. This taxon would be listed as 'sparingly naturalised' in the APC or as 'naturalised' in Hosking *et al*. (2007). Well on the path to naturalising, this population would still be treated as a casual alien since it has not produced reproductively mature plants.

subset of these plants that change the character, condition, form or nature of a natural ecosystem over a substantial area are referred to as "transformers" (Richardson *et al.* 2000). Examples in WA are the invasive grasses *Ehrharta calycina* Sm. (perennial veldt grass) on the Swan Coastal Plain and *Cenchrus ciliaris* L. (buffel grass) in the desert bioregions.

The first three stages of the flow line represent the barriers (geographic, local environmental and reproductive) that await any potentially introduced species before they can become naturalised. To become invasive, species also need to overcome barriers to dispersal within the new region, be able to invade disturbed semi-natural habitats and finally undisturbed habitats, usually aided by particular disturbance regimes.

For a species to be considered naturalised on a census at a state or federal level it should be represented by at least one herbarium collection, plus adequate documentation to demonstrate that it meets or exceeds stages 1 to 4 of the invasion flow line.

Listing of naturalised populations as aliens

Aliens as defined by Pyšek *et al*. (2004) can be alien to any definable area, e.g. continents, islands, biogeographic regions or any political entity (countries, states or provinces). In Australia, exotic aliens (i.e. from overseas) and those from other states in Australia (in the case of WA) are often readily distinguishable as unique entities (non-native taxa) in a flora treatment or checklist by the use of an asterisk preceding the scientific name.

In WA, introducing native species to new habitats within a biogeographic region can have the same effect as an invasive alien from another country or bioregion (e.g. *Melaleuca lanceolata* Otto to the Swan Coastal Plain IBRA bioregion). The definition of 'alien' above should also include habitats within a region. However, taxa of 'mixed' naturalised status do not have a unique identifier on species distribution maps in Florabase or on the Australian Virtual Herbarium at present and rely on a descriptor (native and naturalised populations).

One issue for herbaria is not being able to define what is a naturalised taxon. This is extensively covered in the literature (Kloot 1987; Neson 2000; Richardson *et al.* 2000; Pyšek *et al.* 2004), i.e. if taxa meet stages 1 to 4 (alien cultivated, persisting, casual alien, naturalised alien) they can be listed as naturalised. The issue is really in the usage of collections database searches by researchers not familiar with the caveats of collections. There are numerous examples of taxa naturalised in eastern Australia, but not in WA. One example, noted previously, can be given to illustrate this issue: *Bougainvillea glabra* Choisy, where the distribution maps in the Australian Virtual Herbarium (https://avh.chah.org.au/) or the Atlas of Living Australia (http://www.ala.org.au/) show the two records in WA as a part of the naturalised range. However, the label information on those collections on which this is based explicitly states otherwise: PERTH 7814909, from abandoned Callawa Station, is noted as persisting or in the case of CANB 487147 from Victoria Park it is given as cultivated.

Formalising the invasion flow line

WA should formalise the invasion flow chart in the treatment of alien plant taxa. Four categories should be used:

1 **Alien cultivated**: These are generally not listed or considered in Flora treatments or revisions in Australia. Collections with uncertain localities no latitude or longitude is given on databased collections for maps of species (although they are often valuable in revisions). This is also the case generally if the collection is clearly flagged as cultivated. These species could then be listed in a census, as currently present in WA, so collections are available for reference in horticultural revisions, floras and assist in the naming of new naturalised plant records.

2 **Casual alien**: comprises persisting, sparingly naturalised, waifs etc. They must be represented by at least one herbarium collection, preferably fully documented (numbers of plants, type of spread, area occupied). It is also desirable that the collection is supported by a document/briefing note as listed by Hosking *et al.* (2007). These species may be listed as part of the naturalised flora.

3 **Naturalised alien**: alien plants that have maintained self-sustaining populations for at least 10 years without direct intervention by people (or in spite of human intervention) by recruitment from seed or ramets (tillers, tubers, bulbs, fragments etc.) capable of independent growth.

4 **Invasive alien**: produce reproductive offspring, often in large numbers and at considerable

distances from the parent plants, thus having the potential to spread over a large area. These are the serious agricultural and/or environmental weeds.

We recommend that a method to resolve the issue of what is truly naturalised or is invasive in natural or agricultural landscapes is for checklists or databased collections of species in categories 1 to 4 to have a field showing this status that would be clear in any data search.

Deleting species as naturalised

Conversely, there seem to be few attempts to document the removal of species once they are listed as naturalised in a database, checklist or publication. With this lack of documentation, many inconsistencies can develop over time, for example in the treatments of the family Iridaceae (Iris family) for Victoria by Willis (1970) and Conn (1994). Willis (1970) listed and briefly noted that *Gladiolus* × *colvillei* Sweet (*G. cardinalis* × *tristis*), *Petamenes aethiopica* (L.) Allan, *Babiana stricta* (Aiton) Ker Gawl., *Hexaglottis virgata* (Jacq.) Sweet, *Moraea aristata* (D. Delaroche) Asch. & Graebn. and *Ferraria undulata* L. were locally established in Victoria. Cook (1986) in the *Flora of Australia* noted that *Petamenes aethiopica* (L.) Allan is regarded in Australia as misapplied to the widespread weed *Chasmanthe floribunda* (Salisb.) N.E.Br. and that *Moraea aristata* (D. Delaroche) Asch. & Graebn. is widely cultivated, but only naturalised in South Australia. The Victorian flora treatment by Conn (1994) added *Babiana stricta* (Aiton) Ker Gawl. and *Ferraria undulata* L. to the naturalised flora of Victoria and noted *Hexaglottis virgata* (Jacq.) Sweet had died out, but did not list the other three species, or indicate why they were not considered.

With the ongoing development of electronic checklists, as well as clear guidelines for adding naturalised flora to the WA Plant Census, there should also be clear guidelines for removing species that are no longer considered naturalised in WA. These guidelines should always be specimen-based and transparent to the user of these checklists.

Categories for excluding naturalised species

Three categories should be used for deleting species as naturalised.

Presumed extirpated: in line with the listing of presumed extinct native flora (Gibson 2016), if there are no records of the naturalised species for the past 50 years, it is now deemed to be presumed extirpated from the flora of WA.

Presumed never naturalised: no evidence that the collection (or collections) was from a naturalised population. Often expressly stated in the collecting information to be from a garden or other cultivated origin. Such species can be deemed as never naturalised, even if collections more recent than the 50-year cut-off date for extirpated species are recorded. The lengthy cut-off dates will help guard against too rapid deletion of rarely recorded species that may be reintroduced sporadically from cultivated material. Examples are species such as *Brassica oleracea* L. (wild cabbage) which was recorded as definitely naturalised in 1968 (Red Hill, PERTH 03245764, PERTH 03245772) but has not been recorded in the

wild since 1971 (Lake Grace, PERTH 01352660, PERTH 01420925, PERTH 03242773, PERTH 03242781), so it is approaching deletion.

A second example is *Ageratina adenophora* (Spreng.) R.M. King & H. Rob. (crofton weed). This is a major weed in eastern Australia with one record in WA from Applecross in 1978 (PERTH 0501247). However, a feral population in Nedlands was found in 2014 (PERTH 08930929), resetting the timeframe for deletion to 2064.

Presumed eradicated: deletion of species thought to have been eradicated, after targeted campaigns, until a considerable period has passed to survey for persistent or undocumented populations. In the case of animal pests this is normally 5–10 years (Algar *et. al*. 2020), however, a 20-year period is proposed for plants, to allow for seed bank exhaustion.

Examples of this category are *Bassia scoparia* (L.) A.J. Scott (last recorded in 2000 (Dodd 2004)) or *Agave sisalana* Perrine, only recorded from Rottnest Island in 1986 and 1987, eradicated 1987 (Rippey *et al*. 2003). These species should now be presumed eradicated.

The 22 species listed in Appendix 1 should be removed from the list of naturalised flora of WA. Information on each species suggests that most of them were apparently never naturalised, lacking any accompanying information to suggest they were from wild populations. However, these records do not vanish as the collections on which they are based remain in the WA Herbarium (PERTH). The major change is that the taxa are no longer recognised as a naturalised entity on the WA Plant Census, adding artificially to the number of naturalised weeds. Taxon names would remain listed on the census, and therefore on Florabase, with an explanation that they are not considered naturalised. If documented collections are made that change the status of these species, they can be reinstated.

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Appendix 1: Taxa Proposed for Deletion as Naturalised from Western Australia

Monocotyledons

Alliacaeae

Allium vineale L. (crow garlic)

Recorded from Narrogin in 1946 (PERTH 01997165), Rosa Glen in 1956 (PERTH 01997130) and Mount Barker (PERTH 01997149) in 1964/5. These scattered records have additional information on occurrence though most are probably weeds in crops. Currently, there are no substantiated naturalised populations. Presumed extirpated.

Haemodoraceae

Wachendorfia paniculata L. (rooikanol)

There are two records, from Busselton in 1945 (PERTH 02149664) with no additional information, and Abba River (PERTH 01744550), Busselton in 1953 (PERTH 08892679) and 1963 (PERTH 08892679), apparently naturalised, but not explicitly stated on the collections. There are no further records. Presumed extirpated.

Poaceae

Elytrigia repens (L.) Desv. ex Nevski (quackgrass, English couch)

Only recorded from Woogenellupin in 1925 (PERTH 00306878 and PERTH 00886610), no other information on the collection. Presumed never naturalised.

Avena strigosa Schreb. (bristle oat)

Only recorded from Wongan Hills Research Station in 1951 (PERTH 00342831), no additional information on the collection. Another collection from New Norcia (NSW 293961) in 1984 on wasteland. Upon checking with the collector (Tony Auld) this was also collected at the Research Station. At most a casual alien, presumed never naturalised, but further searches around the now abandoned research station are recommended.

Coix lacryma-jobi L. (Job's tears)

Only recorded from Belmont in 1971 (PERTH 00338044), with no other information on collection. Presumed never naturalised.

The following two species are generally only recorded as the result of seed fall from transportation of materials to ports and do not persist for more than a single generation at a site. They are best described as waifs, "plants of non-native species growing outside of cultivation but not maintaining a viable population for more than one or a few seasons" (Nesom 2000). These species though commonly observed and recorded do not qualify as naturalised flora. They should be listed as casual aliens under the definitions given in this paper.

Secale cereale L. (cereal rye)

Seven collections at PERTH: Osborne Park, 1924 (PERTH 00867713); New Norcia, 1934 (PERTH 00867705); Safety Bay, 1979 (PERTH 00867691); Cockburn, 1995 (PERTH 04364252); Garden Island, 1996 (PERTH 05259703); Churchlands, 2002 (PERTH 06259561) and Yallingup, 2011 (PERTH 0846530). A sterile form is used for soil stabilization, no evidence that it forms naturalised populations. However, frequently seen in large populations because of this usage.

Triticum aestivum L. (wheat)

The earliest record of wheat in Western Australia is from Kings Park, 1934 (CANB 1005.1). At PERTH, there are 22 collections of which six are cultivated: Abrolhos, 1959 (PERTH 00867683); University of WA, 1970 (PERTH 04422937) & 1971 (PERTH 04422902); Northam, 1971 (PERTH 04422953); Williams, 1971 (PERTH 04422929) and Maylands, 1972 (PERTH 04422910). There are 16 from road verges: Yanchep, 1961 (PERTH 00867667); Kwinana, 1979 (PERTH 00867675); Tunney, 1982 (PERTH 00577533); Amelup, 1982 (PERTH 00577545), Stirling Ranges, 1982 (PERTH 00577529 & 00577537), Muckinbuddin, 1988 (PERTH 04652614); Dowerin, 1996 (Perth 04605764); Upper Swan, 1996 (PERTH 04687906); Morawa, 1996 (PERTH 04552830); Mingenew, 1996 (PERTH 04552970); Three Springs, 1996 (PERTH 04551044); Toolibin, 1997 (PERTH 07058179); Woodanilling, 2002 (PERTH 06842925); Moora, 2009 (PERTH 08557128) and Nungarin, 2011 (PERTH 08456461). Recorded only from road verges originating from spilled grain, there is no evidence that this species forms naturalised populations. However, this species is so commonly encountered it may be best considered as a casual alien.

Dicotyledons

Apiaceae

Bupleurum lancifolium Hornem. (lanceleaf thorow wax)

Only recorded from Gnowangerup in 1924 (PERTH 03503720), no additional information on collection. Presumed never naturalised.

Asteraceae

Anthemis cotula L. (stinking mayweed)

Only recorded from Pemberton in 1918 (MEL 01717965A) and Mumballup in 1933 (PERTH 00491403), no other information on collections. Presumed never naturalised.

Helianthus tuberosus L. (Jerusalem artichoke)

Only recorded from Midland in 1972 (PERTH 00426210) and Riverton in 1980 (PERTH 00426067), with no additional information on collections. Presumed never naturalised.

Baccharis viminea DC. (previously regarded in WA as *B. halimifolia* L.; groundsel bush)

Only recorded in Busselton in 1953 (PERTH 0494623), no other information on collection, no other records. No evidence it has been naturalised in WA, but also presumed extirpated. This species is a serious environmental weed in eastern Australia (Sims-Chilton & Panetta 2011) and is a declared prohibited plant in WA under the WA Biosecurity and Agricultural Management Act.

Boraginaceae

Anchusa capensis Thunb. (Cape bugloss/ Cape forget-me-not)

There are two collections: the Cape Riche collection from 1942 states naturalised on the specimen label (PERTH 03615545) and the other collection was made in Fremantle in 1953, no information on collection (PERTH 03615553). More than 70 years since the last verified naturalised collection. Presumed extirpated.

Brassicaceae

Camelina sativa (L.) Crantz (false flax)

A weed of flax, which is now rarely grown in WA. Recorded growing in flax used to produce linseed oil, from Mayanup in 1957 (PERTH 03280632) and Dalyup in 1959 (PERTH 03280640). Presumed extirpated.

Lepidium perfoliatum L. (yellow pepperweed)

Another weed of flax and a minor herb. Only recorded from Darkan in 1976 (PERTH 05609178), no other information on the collection. Presumed never naturalised.

Chenopodiaceae

Atriplex hortensis L. (garden orache)

Collected from Albany in 1965 (PERTH 02381850) and Bunbury in 1966 (PERTH 02381834), no additional information on either collection. Final collection from Albany in 1984 (PERTH 0238184) states cultivated. Presumed never naturalised.

Fabaceae

Trifolium alexandrinum L. (berseem clover)

The two collections, one from Muresk in 1935 (CANB 5082) and the other from Nedlands in 1955 (CANB 51442), both from experimental plots. No evidence of being naturalised. Presumed never naturalised.

Lamiaceae

Moluccella laevis L. (molucca balm, bells of Ireland/shell flower)

Recorded from Gnowangerup in 1924 (PERTH 03722406), Busselton in 1948 (PERTH 03722422) and Bridgetown in 1959 (PERTH 03722414) without further details on any collection. The only known feral record is from a collection, undated, from Southern Hills Station recorded as present in an old pig pen (PERTH 01181483). Presumed extirpated.

Polemiaceae

Navarretia squarrosa (Eschsch.) Hook & Arn. (Californian stinkweed)

Only records are from Pardelup Prison Farm in 1955 (PERTH 03615383, PERTH 03322696) and 1962 (PERTH 03322688), no additional information on any of the three collections. Currently no evidence that this species is naturalised. Presumed extirpated.

Polygonaceae

Rumex sagittatus Thunb. (turkey rhubarb)

Recorded from South Perth as a garden weed (PERTH 03232921, PERTH 03232948) and Claremont in 1962 (PERTH 03232956), with no information. The most recent collection is from Bunbury in 1975, which states cultivated (PERTH 03232964). Presumed never naturalised.

Solanaceae

Cestrum parqui L'Her. (green cestrum/ green poisonberry)

Only collection is from Scarborough in 1980 (PERTH 03679063). Presumed never naturalised.

Physalis hederifolia A. Gray (sticky cape gooseberry)

Only recorded from waste places in Bunbury in 1942 (PERTH 01871722),

with no other information on collection. Presumed never naturalised.

Physalis philadelphica Lam. (tomatillio)

The only record from Spearwood is in 1962 (PERTH 03686531). Presumed never naturalised.

Physalis pubescens L. (downy ground cherry)

A very interesting record from Cambridge Gulf in 1885 (MEL 0091244A), with no other collections from the Kimberley. Other records are from Yatheroo in 1938 (PERTH 03686558) and Bowelling in 1959 (PERTH 03686566) with no additional information on collections. There seems to be no evidence that the species was naturalised in the southwest and it is no longer considered naturalised in the Kimberley. Presumed extirpated.

The terrestrial herpetofauna of the Zuytdorp coast and hinterland of Western Australia: Exceptional richness in a global biodiversity hotspot

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Abstract

The herpetofaunal diversity of the Zuytdorp coast and hinterland was first described in detail by Storr & Harold (1980) who recorded 83 species of frogs and reptiles, in one of several papers on the herpetofauna of the west coast of Western Australia. Over four decades on, additional information shows the area north of the Murchison River (including Kalbarri National Park) and south of Shark Bay (an area of only 12,720 km^2) now supports 118 species comprising 15 frogs, 1 freshwater turtle, 80 lizards and 22 snakes. Excluding marine turtles and sea snakes, this herpetofaunal diversity is comparable to that recorded from other areas on the west coast between Geraldton and Onslow. Aspects of composition, biogeography, endemism, and conservation significance are discussed in the context of the species recorded for the area. This information underlines how much more work is required before an improved understanding of biodiversity and distribution is attained in the globally recognised biodiversity hotspot of southwestern Western Australia. We discuss the contrasting land use of protected areas set aside for the conservation of flora and fauna and non-protected areas under threat from major development projects.

Introduction

Southwestern Australia is recognised globally as one of the world's top biodiversity hotspots (Myers *et al*. 2000; Laurie 2015; Rix *et al*. 2015), based largely on its highly diverse, endemic and threatened flora (Beard *et al*. 2000; Lambers 2014). The Southwest Australian Floristic Region (SWAFR, Beard *et al.* 2000) is a relatively wet to semi-arid island-like continental refuge of *ca.* 300,000 km^2 (Gioia & Hopper 2017). The area also supports exceptional fauna endemism including monotypic genera of frogs (e.g. *Metacrinia nichollsi*, *Myobatrachus gouldii* and *Spicospina flammocaerulea*), turtles (e.g. *Pseudemydura umbrina*), lizards (e.g. *Hesperoedura reticulata*) and snakes

(e.g. *Neelaps calonotos*, *Paroplocephalus atriceps* and *Rhinoplocephalus bicolor*) and species with very restricted distributions (e.g. Kay & Keogh 2012; Doughty & Oliver 2013; Maryan *et al.* 2015a; Webster & Bool 2022; including the area discussed here).

The global biodiversity hotspots represent only 2.5% of the Earth's land surface and have lost at least 70% of their original habitat. Southwestern Western Australia is the most developed and populated part of the State, although the Zuytdorp coast and hinterland are comparatively undisturbed. The Zuytdorp coast and hinterland study area (*ca.* 12,720 km^2) is located on the west coast of Western Australia approximately between latitudes 26°30' and 27°45' and extends south to Kalbarri National Park, east to Galena, Billabong and Overlander Roadhouses on the North West Coastal Highway and north to Tamala and Hamelin on the Useless Loop and Shark Bay Roads, respectively (Fig. 1).

The bioregional location of the study area is at the boundary between the northern Geraldton Sandplains and southern Carnarvon Basin bioregions (Thackway & Cresswell 1995) and hence the meeting point of the state's southwest and eremaean provinces (Burbidge *et al.* 2000). Storr and Harold (1980) provide a summary description of the environment which they divided into three longitudinal zones of western, central and eastern. The regional biogeography, geology, soils and flora of this area have been

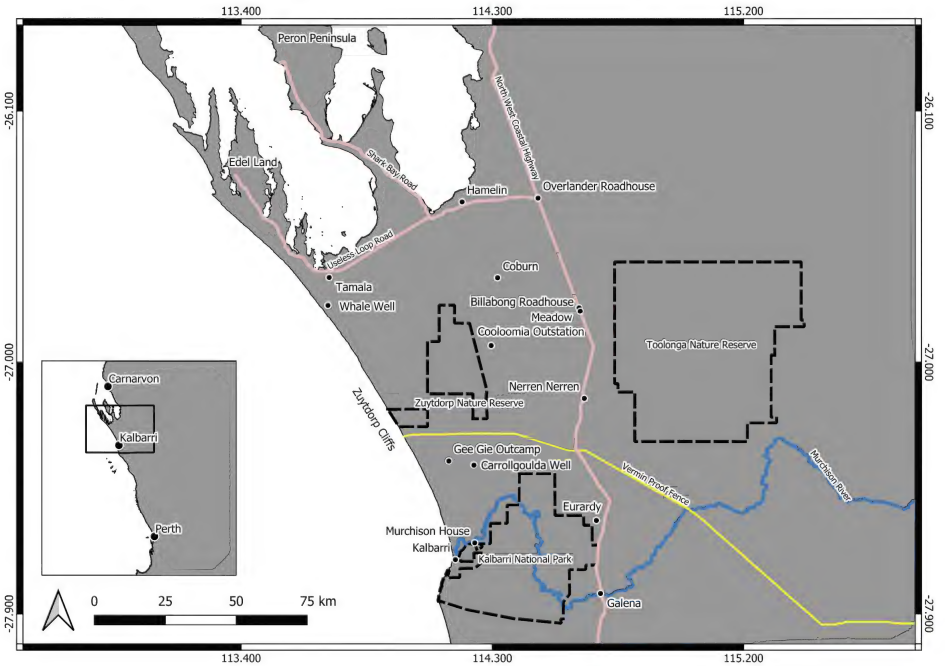

Figure 1. Map of the Zuytdorp coast and hinterland of Western Australia.

reviewed as part of the southern Carnarvon Basin survey by Burbidge *et al.* (2000), Wyrwoll *et al.* (2000), Keighery *et al.* (2000) and Gibson *et al.* (2000) and assessed as part of a biological audit by Desmond & Chant (2001).

The study area includes one regional town (Kalbarri, population ~1,500) and pastoral properties, some of which have undergone changed tenures. The current land use comprises a mixture of both protected gazetted conservation and non-protected pastoral areas (Fig. 1):

- Coburn (100,483 ha): former pastoral station operated by Strandline Resources for the purpose of mineral sand mining.
- Eurardy (30,050 ha) and Hamelin (202,644 ha): former pastoral stations managed by Bush Heritage as nature reserves.
- Kalbarri National Park (186,000 ha), Shark Bay World Heritage Area (332,021 ha excluding marine) and Zuytdorp Nature Reserve (59,000 ha): managed by the Department of Biodiversity, Conservation and Attractions (DBCA).
- Murchison House (140,000 ha): active pastoral station.
- Nerren Nerren/Meadow (154,711 ha): active pastoral stations.
- Tamala (72,272 ha): active pastoral station within the Shark Bay World Heritage Area.

The increased focus of major development projects for mining and renewable energy in the area presents a conundrum of proposed economic development occurring at the expense of irreparable environmental damage that will fragment the unique landforms and biota of the region. Thus, a revised evaluation of the herpetofauna in this global biodiversity hotspot is warranted considering this anthropogenic disturbance as the only detailed assessment of the herpetofauna of the region was published over four decades ago (Storr & Harold 1980). The increased level of systematic surveys, combined with additional opportunistic sampling by field herpetologists and taxonomic revisions of certain species, highlights the need for an updated inventory that refines the herpetofaunal diversity of the Zuytdorp coast and hinterland (Table 1, marine species being excluded due to lack of collection records, OZCAM 2022).

Regarding vertebrate richness, there is no easy resolution to accurately define this metric in areas using museum specimens while considering the differential effort expended in sampling (How & Cowan 2006). Therefore, assessments of faunal assemblage richness, particularly in poorly surveyed regions of which there are many in Western Australia, are often made using the most conservative information available of the basic species list (How & Cowan 2006). In this case, the first detailed inventories of herpetofauna on the west coast of Western Australia (including the area discussed here) were carried out between 1978 and 1985 by Glen Storr and other contemporary contributing colleagues in which the biogeographical relationships and habitat preferences of the terrestrial herpetofauna were documented (Storr & Harold 1978, 1984, 1985; Storr & Hanlon 1980; Storr *et al.* 1983). Similar to the area discussed here, their species numbers have been updated as follows (also excluding introduced and marine species):

Table 1. Terrestrial herpetofauna species list for the Zuytdorp coast and hinterland based on Western Australian Museum records (OZCAM 2022), field observations by naturalists and systematic surveys by environmental consultancy companies and Bush Heritage Australia.

Limnodynastidae – Large Ground Frogs
Heleioporus albopunctatus
Heleioporus psammophilus
Limnodynastes dorsalis
Neobatrachus kunapalari
Neobatrachus pelobatoides
Neobatrachus sutor
Neobatrachus wilsmorei

Myobatrachidae – Small Ground Frogs
Arenophryne rotunda
Arenophryne xiphorhyncha
Crinia pseudinsignifera
Myobatrachus gouldii
Pseudophryne guentheri
Pseudophryne occidentalis

Pelodryadidae – Tree Frogs
Cyclorana maini
Litoria moorei

Chelidae – Freshwater Turtles
Chelodina steindachneri

Carphodactylidae – Large Gondwanan Geckos
Nephrurus levis occidentalis
Underwoodisaurus milii

Diplodactylidae – Small Gondwanan Geckos
Crenadactylus occidentalis
Diplodactylus klugei
Diplodactylus ornatus
Diplodactylus pulcher
Lucasium alboguttatum
Lucasium squarrosum
Rhynchoedura ornata
Strophurus michaelseni
Strophurus spinigerus spinigerus
Strophurus strophurus

Gekkonidae – Cosmopolitan Geckos
Gehyra variegata
Heteronotia binoei

Pygopodidae – Legless Lizards
Aprasia haroldi
Aprasia smithi
Delma australis
Delma concinna concinna
Delma concinna major
Delma fraseri
Delma grayii
Delma tincta
Lialis burtonis
Pletholax edelensis
Pletholax gracilis
Pygopus lepidopodus
Pygopus nigriceps

Agamidae – Dragons
Ctenophorus adelaidensis
Ctenophorus butlerorum
Ctenophorus maculatus
Ctenophorus nuchalis
Ctenophorus reticulatus
Ctenophorus rubens
Ctenophorus scutulatus
Diporiphora amphiboluroides
Gowidon longirostris
Moloch horridus
Pogona minor minor

Scincidae – Skinks

Cryptoblepharus buchananii
Cryptoblepharus plagiocephalus
Ctenotus alleni
Ctenotus australis
Ctenotus fallens
Ctenotus mimetes
Ctenotus pantherinus
Ctenotus schomburgkii
Ctenotus severus
Ctenotus youngsoni
Ctenotus zastictus
Cyclodomorphus branchialis
Cyclodomorphus celatus
Egernia depressa
Egernia formosa
Egernia stokesii badia
Eremiascincus richardsonii
Lerista connivens
Lerista elegans
Lerista humphriesi
Lerista kendricki
Lerista macropisthopus fusciceps
Lerista macropisthopus galea
Lerista micra
Lerista miopus
Lerista planiventralis decora
Lerista praepedita
Lerista uniduo
Lerista varia
Liopholis inornata
Menetia greyii
Menetia surda cresswelli
Morethia butleri
Morethia lineoocellata
Morethia obscura
Tiliqua occipitalis
Tiliqua rugosa palarra
Tiliqua rugosa rugosa

Varanidae – Goannas

Varanus brevicauda
Varanus caudolineatus
Varanus eremius
Varanus giganteus
Varanus gouldii
Varanus panoptes rubidus
Varanus tristis

Typhlopidae – Blind Snakes

Anilios australis
Anilios grypus
Anilios hamatus
Anilios leptosoma
Anilios obtusifrons

Pythonidae – Pythons

Antaresia childreni
Aspidites ramsayi

Elapidae – Venomous Land Snakes

Brachyurophis approximans
Brachyurophis fasciolatus fasciolatus
Brachyurophis semifasciatus
Echiopsis curta
Demansia calodera
Demansia reticulata
Narophis bimaculatus
Pseudechis australis
Pseudonaja mengdeni
Pseudonaja modesta
Simoselaps bertholdi
Simoselaps littoralis
Suta fasciata
Suta gouldii
Suta monachus

- Geraldton region of 109 species (Maryan 2005, as central west coast) and 117 (unpublished data),
- Shark Bay region of 107 species (Storr & Harold 1990) and 110 (unpublished data),
- Exmouth region of 89 species (Kendrick 1993); 90 (Beranek *et al*. 2021); 93 (Maryan & Gaikhorst 2022) and 120 (unpublished data),
- Lake MacLeod region of 111 species (unpublished data),
- Onslow region of 115 species (unpublished data).

The diversity of the west coastal regions is remarkably similar with Exmouth having the greatest, as noted by How & Cowan (2006) for the Cape Range-Exmouth Gulf area, while Geraldton and the area discussed here share almost identical richness. To put this in perspective, and highlight the diversity of the area discussed here, the systematic survey of the much larger southern Carnarvon Basin recorded 133 terrestrial species from a 75,000 km^2 study area (McKenzie *et al*. 2000).

Detailed systematic surveys conducted in areas on the Zuytdorp coast and hinterland include five trapping quadrats labelled Zuytdorp (ZU1–5) along the vermin-proof fence in the south, as part of the southern Carnarvon Basin survey (Fig. 1, McKenzie *et al*. 2000). Since then, our knowledge and understanding of the regional herpetofauna has been greatly improved by the increased level of systematic surveys and monitoring, particularly of the Vulnerable Hamelin Skink *Ctenotus zastictus*, by environmental consultancy companies due to development projects in the area (e.g. Ninox 2004, 2006; URS 2014; AECOM 2020) and, currently by Bush Heritage Australia on the pastoral stations Hamelin and Eurardy (see Discussion). Several taxonomic revisions and descriptions of new species have also enhanced the richness of the Zuytdorp coast and hinterland (e.g. Storr 1984; Shea & Miller 1995; Aplin & Adams 1998; Doughty & Edwards 2008; Ellis *et al*. 2017; Kealley *et al*. 2020).

Composition

The 51 genera and 118 terrestrial species of frogs and reptiles are distributed in 14 families (Table 1). Of the 118 species known to occur in the study area, 27 (23%) are endemic to southwestern Australia and four are endemic just to the study area. Complimenting this comparatively high proportion of endemism are the 19 and 13 species, respectively, attaining their northern and southern distributional limits. We found no evidence of introduced amphibian or reptile species. The zoogeographic relationships of the species are briefly discussed in family sequence.

LIMNODYNASTIDAE – Large Ground Frogs

Limnodynastid frogs are quite diverse in the study area with seven species. Four species are endemic to southwestern Australia, attaining their northern limit of known distribution in the study area: *Heleioporus albopunctatus*, *H. psammophilus*, *Limnodynastes dorsalis* and *Neobatrachus pelobatoides*. *Neobatrachus* has four species of which *N. kunapalari*, *N. sutor* and *N. wilsmorei* are widespread throughout the semiarid and arid regions of Western Australia.

MYOBATRACHIDAE – Small Ground Frogs

Myobatrachid frogs are represented in the study area by six species. Two genera, *Arenophryne*, *Myobatrachus* and five species are endemic to southwestern Australia. *Crinia pseudinsignifera*, *Myobatrachus gouldii*, *Pseudophryne guentheri* and *P. occidentalis* attain their northern limit of known distribution in the study area, while *Arenophryne rotunda* attains its southern distributional limit. *Arenophryne xiphorhyncha* is entirely endemic to the study area. *Pseudophryne occidentalis* is represented in the study area and just east of Shark Bay by an apparent disjunct population, otherwise, this species is widespread throughout the semiarid regions of Western Australia.

PELODRYADIDAE – Tree Frogs

One species, *Cyclorana maini* is widespread throughout the arid regions of Western Australia occurring in the study area just east of Shark Bay. *Litoria moorei* is endemic to southwestern Australia attaining its northern limit of known distribution in the study area, specifically the Murchison River. This family is poorly represented in southwestern Australia with only three species, a pattern that may be attributed to the drier conditions, as they are more diverse in Australia's tropical and eastern regions (Sanders 2021).

CHELIDAE – Freshwater Turtles

Chelodina steindachneri is endemic to Western Australia and is a widespread arid-adapted species occurring in watercourses between the De Grey and Irwin Rivers. The southern limit of its known distribution is on the central west coast (Maryan 2005).

CARPHODACTYLIDAE – Large Gondwanan Geckos

Australia's only endemic reptile family is represented in the study area by two species. *Nephrurus levis* (3 subspecies) is widespread throughout the semiarid and arid regions of Western Australia, while *Underwoodisaurus milii* is widespread across southern Australia.

DIPLODACTYLIDAE – Small Gondwanan Geckos

Diplodactylid geckos are represented in the study area by 10 species. Two of these species are endemic to southwestern Australia: *Strophurus michaelseni* and *S. spinigerus* (2 subspecies). *Diplodactylus klugei* attains its southern limit of known distribution in the study area and southeast of Shark Bay. Those species with primarily west coastal distributions are *Crenadactylus occidentalis*, *Diplodactylus klugei*, *D. ornatus*, *Lucasium alboguttatum* and *Strophurus michaelseni* (restricted to semiarid west coast and hinterland). *Diplodactylus pulcher*, *Lucasium squarrosum*, *Rhynchoedura ornata* and *Strophurus strophurus* are widespread throughout the semiarid and arid regions of Western Australia.

GEKKONIDAE – Cosmopolitan Geckos

Two of Australia's most widespread geckos occur in the study area. *Gehyra variegata* occurs over most of the southern half of Western Australia extending east to the western interior of South Australia. *Heteronotia binoei* occurs throughout most of Australia

excluding the cooler southerly parts and are often the most abundant reptiles in arid areas.

PYGOPODIDAE – Legless Lizards

Legless lizards are exceptionally diverse in the study area with 12 species. One genus (*Pletholax*) and six species (*Aprasia haroldi*, *Delma concinna* [2 subspecies], *D. fraseri*, *D. grayii*, *Pletholax edelensis* and *P. gracilis*) are endemic to southwestern Australia. *Delma concinna* (almost so) and *Pletholax gracilis* attain their northern limit of known distribution in the study area while *Aprasia haroldi* (only recently recorded at Coburn, AECOM 2020) and *Pletholax edelensis* attain their southern distributional limit. *Aprasia smithi* is restricted to the semiarid central west coast and hinterland. *Delma grayii* has a relatively restricted west coast distribution. *Delma australis*, *D. fraseri* and *D. tincta* are widespread in southwestern Australia and throughout semiarid, arid and tropical Australia. *Lialis burtonis* is widespread throughout the greater part of Australia. *Pygopus lepidopodus* and *P. nigriceps* have widespread southern and northern distributions, respectively, that overlap in the study area.

AGAMIDAE – Dragons

Dragons are represented in the study area by 11 species. Two of these species are endemic to southwestern Australia: *Ctenophorus adelaidensis* and *C. butlerorum*. The same species attain their northern and southern limits of known distribution, respectively, in the study area, *C. adelaidensis* is represented by an apparent disjunct population which is possibly an artefact of collecting north of Geraldton. *Ctenophorus maculatus*, *C. nuchalis*, *C. reticulatus*, *Diporiphora amphiboluroides*, *Gowidon longirostris*, *Moloch horridus* and *Pogona minor* (3 subspecies) are widespread throughout the temperate, semiarid and arid regions of Western Australia. *Ctenophorus rubens* is represented in the study area by a significantly disjunct population, otherwise, this species is primarily distributed on the arid west coast and hinterland to the east and north of the study area.

SCINCIDAE – Skinks

Skinks are the most diverse family (the trend throughout Australia) in the study area with 35 species. The two most diverse Australian skink genera, *Ctenotus* and *Lerista* are represented with 9 and 11 species, respectively. Seven species are endemic to southwestern Australia: *Ctenotus alleni*, *C. australis* (almost so), *C. youngsoni*, *C. zastictus*, *Cyclodomorphus branchialis* (almost so), *Lerista humphriesi* and *L. kendricki*. From these, *C. zastictus* and *L. humphriesi* are endemic to the study area. *Ctenotus alleni*, *Cyclodomorphus branchialis*, *Lerista kendricki* and *Morethia butleri* attain their northern limit of known distribution in the study area, while *Ctenotus severus*, *C. youngsoni*, *Lerista micra*, *L. uniduo* and *L. varia* attain their southern distributional limit.

Several skink species have extensive west coastal distributions: *Ctenotus australis*, *C. fallens*, *Cyclodomorphus celatus*, *Lerista elegans*, *L. miopus*, *L. planiventralis* [3 subspecies], *L. praepedita* and *Morethia lineoocellata*. *Egernia formosa* is represented in the study area by an apparent disjunct population, otherwise, this species is

widespread throughout the semiarid and arid Pilbara regions of Western Australia. *Egernia stokesii* (3 subspecies) occurs in fragmented populations on Western Australia's west coast (mostly islands), semiarid regions and eastern interior of Australia. *Liopholis inornata* has only been recently recorded in the study area, otherwise, it is widely distributed in semiarid and arid southern Australia. The remaining species have wider distributions in Western Australia or are widespread throughout the greater part of Australia.

VARANIDAE – Goannas

Goannas are quite diverse in the study area with seven species with none endemic to southwestern Australia. *Varanus brevicauda* is represented in the study area by a significant disjunct population, otherwise, this species is widespread throughout the arid regions of Western Australia. *Varanus caudolineatus* is endemic to Western Australia and is widespread throughout the semiarid and arid regions. *Varanus giganteus* and *V. panoptes* (2 subspecies) are recorded in the study area extending current distributional accounts (e.g. Thompson *et al*. 2005), otherwise, these species including *V. gouldii* and *V. tristis* are widespread throughout temperate, arid, and tropical Australia.

TYPHLOPIDAE – Blind Snakes

Blind snakes are represented in the study area by five species. One species, *Anilios obtusifrons* is endemic to southwestern Australia and has a very restricted known range just south of Kalbarri (Ellis *et al*. 2017). *Anilios grypus* attains its southern limit of known distribution in the study area. *Anilios leptosoma* is restricted to the semiarid central west coast and hinterland. *Anilios australis*, *A. grypus* and *A. hamatus* are widespread throughout the temperate, semiarid and arid regions of Western Australia.

PYTHONIDAE – Pythons

Pythons are represented in the study area by two species with none endemic to southwestern Australia. *Antaresia childreni* is widespread throughout the greater part of Australia. *Aspidites ramsayi* has only been recently recorded in the study area at Coburn, otherwise, it is widely distributed in arid Australia; however, the populations in Western Australia appear disjunct (Maryan 2002).

ELAPIDAE – Venomous Land Snakes

The terrestrial venomous snake fauna in the study area is diverse with 15 species, with none endemic to southwestern Australia. *Brachyurophis semifasciatus*, *Echiopsis curta* and *Suta gouldii* attain their northern limit of known distribution in the study area, while *Brachyurophis approximans* and *Demansia calodera* attain their southern distributional limit. The small fossorial snakes are well represented with three *Brachyurophis* species, the monotypic *Narophis* and two *Simoselaps* species. Endemic to Western Australia, *Brachyurophis approximans*, *Demansia reticulata* and *Suta fasciata* are widespread throughout the temperate, semiarid and arid regions; *Demansia calodera* and *Simoselaps littoralis* have extensive west coastal distributions. *Brachyurophis fasciolatus* (2 subspecies), *B. semifasciatus*, *Narophis bimaculatus*, *Simoselaps bertholdi* and *Suta monachus*

are also widespread throughout the temperate, semiarid and arid regions of Western Australia. *Echiopsis curta* is essentially coastal in distribution with disjunct populations across southern Australia. The remaining species, *Pseudechis australis*, *Pseudonaja mengdeni* and *P. modesta* are widespread throughout the greater part of Australia.

Adjacent Areas

Apart from the detailed inventories of the Geraldton (Storr *et al*. 1983; Maryan 2005) and Shark Bay (Storr & Harold 1978, 1990) regions, there have been limited systematic surveys conducted in adjacent areas. To the immediate east, a detailed systematic survey of Toolonga Nature Reserve (421,553 ha) recorded one frog and 31 reptile species (Burbidge *et al*. 1980). That nature reserve adjoins Muggon Station, a former pastoral station acquired by the Department of Conservation and Land Management (CALM = DBCA) in the mid-1990s. The southern Carnarvon Basin survey included trapping quadrats on Nanga Station (NA1–5), Nerren Nerren Station (NE1–5), Edel Land (EL1–2) and Peron Peninsula (PE1–5) (Fig. 1, McKenzie *et al*. 2000). From these surveys, *Delma butleri*, *D. nasuta*, *Ctenotus leonhardii* and *C. u. uber* were recorded that could potentially occur in the study area.

Several species recorded in the Geraldton and Shark Bay regions appear absent from the study area. These attain their northern distributional limits, for example *Aprasia repens*, *Lerista distinguenda*, *Morelia imbricata* and *Neelaps calonotos* (Maryan 2005), or comprise disjunct populations, e.g. *Christinus marmoratus* and *Egernia kingii* (Storr & Harold 1990). Considering the geographic proximity of some species, the already impressive herpetofaunal diversity of the study area is possibly underestimated. For many Australian species of frogs and reptiles, their distributions remain uncertain and with ongoing fieldwork in poorly surveyed regions such as the study area, range extensions are a regular occurrence (Maryan & Gaikhorst 2022). For example, see *Delma concinna* and *Liopholis inornata* below and *Neelaps calonotos* was considered restricted to the Swan Coastal Plain until being recorded on the Geraldton Sandplains (Storr *et al*. 2002; Maryan 2005). Storr & Harold (1980) listed species likely to be recorded in the study area that are now confirmed as present: *Ctenotus lesueurii* = *C. australis*, *Eremiascincus richardsonii*, *Tiliqua occipitalis* and *Vermicella f. fasciolata* = *Brachyurophis f. fasciolatus*.

Biogeography and Further Study

Several species and subspecies attain distributional limits in the study area (see Discussion). The peculiarities of some disjunct reptile distributions on the west coast of Western Australia were noted by Storr *et al.* (1983) and Maryan (2005). Generally, the extent of these gaps makes it difficult to distinguish between species absence, very low density, or lack of overall survey effort. For some small fossorial species (e.g. genera *Aprasia*, *Lerista* and snakes) it often requires a considerable length of time to reveal their presence, and this is only achieved by conducting extensive trapping programs (How & Shine 1999). However, based on personal observations when conditions are optimal, it is possible to reveal

reasonable numbers of these small elusive reptiles through active searching.

The records of *Arenophryne rotunda* from Whale Well on Tamala and *A. xiphorhyncha* from Cooloomia Outstation (~ 50 km apart) coincide with the different soil types in the study area (Doughty & Edwards 2008). *Diplodactylus klugei* and *D. pulcher* have widespread coastal and semiarid to arid distributions that overlap in the study area. Some degree of partitioning occurs on Hamelin Station Reserve, where *D. klugei* generally prefers the heavy, often stony soils and *D. pulcher* the light soils (pers. obs.). The nominate form of *Delma concinna* has been recorded from the study area at 23 km NW of Carrollgoulda Well, being previously only known north to Coolimba (Storr *et al.* 1990), substantially reducing its disjunction with the Shark Bay subspecies *D. c. major* (~72 km apart). In the case of the two *Pletholax* species, the disjunction between *P. gracilis* and *P. edelensis* has been substantially reduced to ~66 km from 55 km NNW of Kalbarri to Coburn. *Liopholis inornata* has been recorded from the study area at 30 km NNW of Eurardy Homestead and on Hamelin Station Reserve, which are located between the core distribution west to East Yuna and a single record on the Peron Peninsula at Shark Bay (Storr *et al.* 1999). Two subspecies of *Tiliqua rugosa* are recorded from the study area, with *T. r. rugosa* at Gee Gie Outcamp and *T. r. palarra* from 5 km S of Tamala Homestead. Shea (2000) noted for *T. r. palarra*, in the vicinity of the Murchison River, a relatively narrow zone of intermediacy ~70 km long with the nominate form. If this is the case, further study is required to clarify their relationships. *Brachyurophis approximans* and *B. semifasciatus* have widespread distributions approaching each other in the study area at Coburn for *B. approximans* and 18 km NNW of Gee Gie Outcamp for *B. semifasciatus* (~40 km apart). Storr (1979) noted the two *Brachyurophis* species collected within 8 km of each other in the Wiluna district from different habitats.

Mostly confined to Edel Land peninsula and Dirk Hartog Island, *Arenophryne rotunda*, *Aprasia haroldi*, *Pletholax edelensis*, *Ctenophorus butlerorum* and *Ctenotus youngsoni* extend south to the study area. Also of interest, is the transition along the coast between the yellow and white-eyed forms of *Strophurus s. spinigerus* and between the white rings of skin on the tail in southwest populations of *S. strophurus*, including the study area, and the orange or yellow rings elsewhere (Storr *et al.* 1990). Some species have disjunct populations in the study area. For example, *Varanus brevicauda* is known from a single specimen on central Peron Peninsula and an isolated belt of open Mallee and *Triodia* growing on reddish sandplains on Hamelin Station Reserve and Coburn. The nearest other populations are from Mardathuna and Kennedy Range (~ 200 km apart). It would be important to determine the genetic affinities of these geographically isolated populations. A disjunct population of *Ctenophorus rubens* is also restricted to that isolated habitat and *Ctenotus zastictus* is found nowhere else. Also requiring study are the apparent disjunct populations of *Pseudophryne occidentalis*, *Ctenophorus adelaidensis* and *Egernia formosa* in the study area (OZCAM 2022).

The complex geographic history involving a combination of geological activity and changes in sea level has

played a major role in shaping the extensive sandy areas along the west coast of Australia (e.g. Hocking *et al*. 1987; Rabosky *et al*. 2004; Edwards *et al*. 2012). For example, the significant levels of genetic divergence seen in the southwestern Australian endemic *Aprasia repens* species group could be related to habitat specialisation and low dispersal capability that have likely generated isolation and subsequent genetic divergence (Maryan *et al*. 2015b). This hypothesis seems plausible considering the parallel divergence seen in other frogs and reptiles inhabiting sandy habitats along the west coast (e.g. *Arenophryne* Doughty & Edwards 2008; *Ctenophorus* Melville *et al*. 2008, Edwards & Hutchinson 2023; *Ctenotus* Kay & Keogh 2012; *Lerista* Amey & Edwards 2017).

Endemism and Conservation Significance

The four endemic taxa in the study area are *Arenophryne xiphorhyncha*, *Ctenotus zastictus*, *Lerista humphriesi* and *Anilios obtusifrons* (Fig. 2). *Arenophryne xiphorhyncha* is only known from a belt of sandplain habitats 120 km in linear distance, consequently reducing the distribution of true *A. rotunda* to a similarly restricted distribution (Doughty & Edwards 2008). Both species qualify as short-range endemics (Harvey 2002) requiring evaluations of their conservation status.

Ctenotus zastictus represents one of the most geographically restricted vertebrates in Australia. It is only known from an isolated belt of *Eucalyptus* and *Triodia* (50 km^2) on Hamelin Station Reserve and Coburn (Chapple *et al*. 2019; Singhal *et al*.

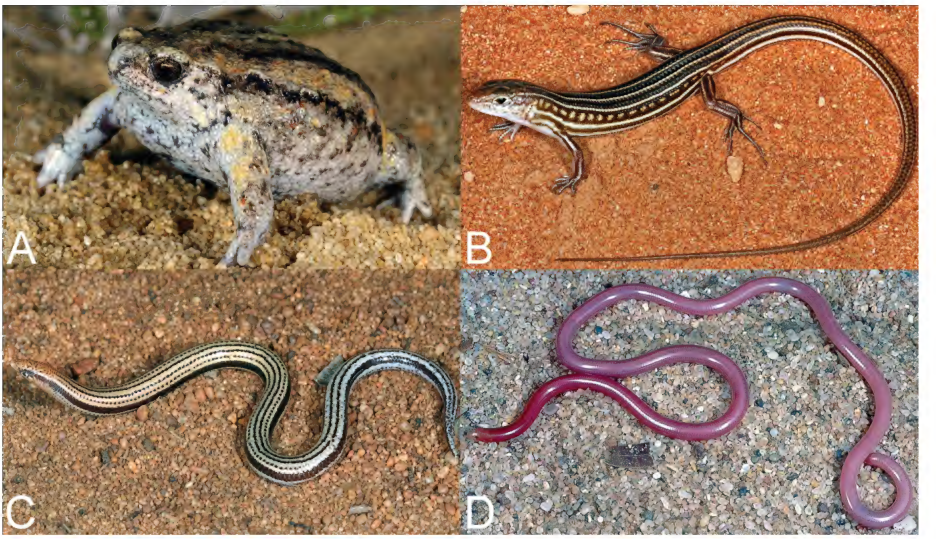

Figure 2. The endemic taxa of the Zuytdorp coast and hinterland (A) *Arenophryne xiphorhyncha*, (B) *Ctenotus zastictus*, (C) *Lerista humphriesi* and (D) *Anilios obtusifrons*. Photos: B. Maryan.

2022) and, is consequently listed as Vulnerable under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) and Near Threatened by the International Union for Conservation of Nature (IUCN 2021). Mining activity on Coburn has resulted in a threatened fauna management plan that includes monitoring of this species (URS 2014), while on Hamelin the species is monitored annually by trapping programs to gather information on population trends (Bush Heritage Australia 2023a).

Lerista humphriesi is restricted to the *Acacia*-dominated sandplains and appears to be patchily distributed (pers. obs.) and less plentiful than the morphologically similar *L. praepedita*. It is yet to be recorded in Kalbarri National Park or Hamelin Station Reserve, suggesting its overall geographic range may be more restricted than previously recorded. Further surveys are required to gather information on local distribution and relative abundance. It is currently listed as a Priority 3 poorly known species in Western Australia and considered to be Least Concern by the IUCN (2021), based on the broad justification of 'its population is presumed stable and there are no major threats currently affecting its population' (Chapple *et al.* 2019).

Anilios obtusifrons is endemic to the study area based on the three known specimens from just south of Kalbarri. The distribution of this species is very small (10 km^2), although it may be more widely distributed (Ellis *et al.* 2017). Blind snakes are notoriously difficult to survey due to their subterranean habits, therefore any information acquired on this range-restricted species will be important.

The conservation status of *Cyclodomorphus branchialis* was highlighted as a concern by Shea & Miller (1995) owing to its apparent low density in an area heavily cleared for agriculture. In the study area, *C. branchialis* attains its northern limit of distribution inhabiting heavy soils with *Acacia*, often in association with rocky areas (pers. obs.). With this habitat specificity in mind, it could occur on Eurardy Station Reserve. The species is currently listed as Vulnerable under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act) and Near Threatened by the International Union for Conservation of Nature (IUCN 2021).

One subspecies, *Egernia stokesii badia* is currently listed as Endangered under the Commonwealth Environment Protection and Biodiversity Act 1999 (EPBC Act) having endured a marked decline due to land clearing and it currently occurs in isolated small subpopulations (How *et al.* 2003; Chapple *et al.* 2019). This species also displays long-term social and genetic monogamy (Chapple 2003) that further exacerbates its vulnerability to anthropogenic disturbance. In the study area, it is mostly confined to large intact areas of York Gum woodlands that account for up to 22% of habitat on Eurardy Station Reserve, but skinks are patchily distributed being reliant on suitable hollow logs and surrounding low vegetation (Bradley *et al.* 2022; pers. obs.). A taxonomic revision of *E. stokesii* is overdue, considering preliminary studies suggesting subspecific classifications are unwarranted and unnamed taxa await formal description. The current IUCN listing of Least Concern for the species

will require reassessment after the taxonomy is resolved (Chapple *et al*. 2019).

Aspidites ramsayi is widespread throughout arid Australia and variously listed under Commonwealth and State/Territory legislation as either Priority 1 (for southwestern population), Vulnerable, Near Threatened or Rare and, overall is Least Concern by the IUCN (Chapple *et al*. 2019). In southwestern Australia, particularly the wheatbelt, the population has suffered a severe decline due to land clearing and probably predation by feral animals (e.g. Smith 1981; Pearson 1993; Maryan 2002). A population is known from Peron Peninsula in the Shark Bay World Heritage Area. In the study area, the field observations of two individuals in 2021 at Coburn raise the prospect it may be more widely distributed. However, the secretive habits of this python, spending considerable time underground in burrows, makes them very difficult to survey (e.g. Bruton 2013).

Discussion

Southwestern Australia is a globally recognised biodiversity hotspot owing to the loss of over 70% of its original vegetation and contains at least 1,500 species of vascular plants found nowhere else on Earth and, hence by definition, is an area in a conservation crisis. The high levels of diversity and endemism in plants and animals, including invertebrates (e.g. Wardell-Johnson & Horwitz 1996; Belk 1998; Beard *et al*. 2000; Myers *et al*. 2000; Harvey 2002; How & Cowan 2006; Bush *et al*. 2007; Lambers 2014; Laurie 2015; Rix *et al*. 2015, 2017, 2018), is unparalleled elsewhere in the state, and only equalled by the forests of eastern Australia (Critical Ecosystem Partnership Fund 2021).

An example of the biological richness in southwestern Australia, is shown in the diverse terrestrial herpetofauna of the Zuytdorp coast and hinterland, that is partly attributed to its location at the flora transitional zone between the southwest and eremaean bioregions and is therefore an area of significant vegetation change. The study area intersects the Geraldton Sandplains and Carnarvon Basin bioregions on the west coast, which combined have significantly high diversity, endemism, threatened/priority and range-restricted frog and reptile species (How & Cowan 2006). The area contains the largest and richest remnant of the original kwongan vegetation of the northern sandplains (Beard 1990; Lambers 2014). The regionally significant Kalbarri National Park alone boasts over a thousand plant species (Keighery *et al*. 2000) and is well known for its scenic sandstone gorges along the Murchison River and wildflowers that in turn generate much local and international tourism as well as public interest. However, apart from unpublished fauna studies by Bannister (1969), this national park is yet to be systematically surveyed (Maryan 2005; Department of Parks and Wildlife 2015).

Reflecting the location of the study area at the meeting point of the state's southwest and eremaean provinces are the mixed assemblages of herpetofauna species attaining their northern (e.g. *Heleioporus albopunctatus*, *H. psammophilus*, *Limnodynastes dorsalis*, *Neobatrachus pelobatoides*, *Crinia pseudinsignifera*, *Myobatrachus gouldii*,

Pseudophryne guentheri, *P. occidentalis*, *Litoria moorei*, *Delma concinna*, *Pletholax gracilis*, *Ctenophorus adelaidensis*, *Ctenotus alleni*, *Cyclodomorphus branchialis*, *Lerista kendricki*, *Morethia butleri*, *Brachyurophis semifasciatus*, *Echiopsis curta* and *Suta gouldii*) and southern (e.g. *Diplodactylus klugei*, *Ctenotus severus*, *Lerista micra*, *L. uniduo*, *L. varia*, *Anilios grypus*, *Brachyurophis approximans* and *Demansia calodera*) distributional limits, combined with several species (e.g. *Cyclorana maini*, *Diporiphora amphiboluroides*, *Varanus giganteus* and *V. panoptes*) characteristic of the arid interior extending to the area. The species, *Arenophryne rotunda*, *Aprasia haroldi*, *Pletholax edelensis*, *Ctenophorus butlerorum* and *Ctenotus youngsoni* are mostly confined to Edel Land peninsula and Dirk Hartog Island, extending south to the study area highlighting the uncertain distributions of many taxa. Several species have significant disjunct populations in the study area requiring further study of their genetic affinities (e.g. *Egernia formosa* and *Varanus brevicauda*). The area is particularly rich in fossorial species and includes the uniquely adapted frogs *Arenophryne* and *Myobatrachus*, two species of *Aprasia*, 11 species of *Lerista*, five species of *Anilios* and six species of small elapid snakes in the genera *Brachyurophis*, *Narophis* and *Simoselaps*. There are eight endemic and/or conservation-significant species in the area, including four range-restricted taxa found nowhere else. These range-restricted endemic taxa represent a particularly significant component of the endemic fauna of Western Australia as they occupy very restricted ranges (each < 0.4% of the State) and must be regarded as highly vulnerable to anthropogenic changes (How & Cowan 2006). The federally endangered *Egernia stokesii badia* and priority listed *Lerista humphriesi* require further surveys in the study area to determine the extent of their occurrence.

The Zuytdorp coast and hinterland are conserved in the southern part of the Shark Bay World Heritage Area adjoining the Hamelin Station Reserve, extending a corridor of nature reserves south from Shark Bay to Eurardy Station Reserve and then Kalbarri National Park. Bush Heritage Australia has made significant holistic conservation outcomes on Hamelin and Eurardy by de-stocking, feral animal control, revegetation, systematic surveys and monitoring (Bush Heritage Australia 2023b, c). There is also a proposal to create a large 1.2 million ha land-to-sea corridor of conservation areas to consolidate fragmented existing reserves as part of the 'Shark Bay World Heritage to Wooleen' expansion (Douglass *et al.* 2019).

In contrast, non-protected areas face the opposite prospect of development projects, such as has occurred on Coburn for mineral sand mining (Strandline Resources Limited 2023) and there are plans to develop renewable energy consisting of green hydrogen and ammonia production powered by hundreds of wind turbines (including offshore) and solar panels, combined with infrastructure such as a purpose-built water treatment and desalination plant, and road construction to access and maintain the facilities (Carroll 2022; CSIRO HyResource 2022). This substantial development project presents a problem by achieving renewable energy outcomes at the expense of

causing irreparable environmental damage by contributing towards more land clearing within the globally recognized biodiversity hotspot of southwestern Australia. All the existing cleared land south of Kalbarri, with arguably similar wind and solar yields, should be considered as an alternative location for development projects.

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From Field and Study

The origin of Tiger Snakes on Carnac Island, Western Australia: an update

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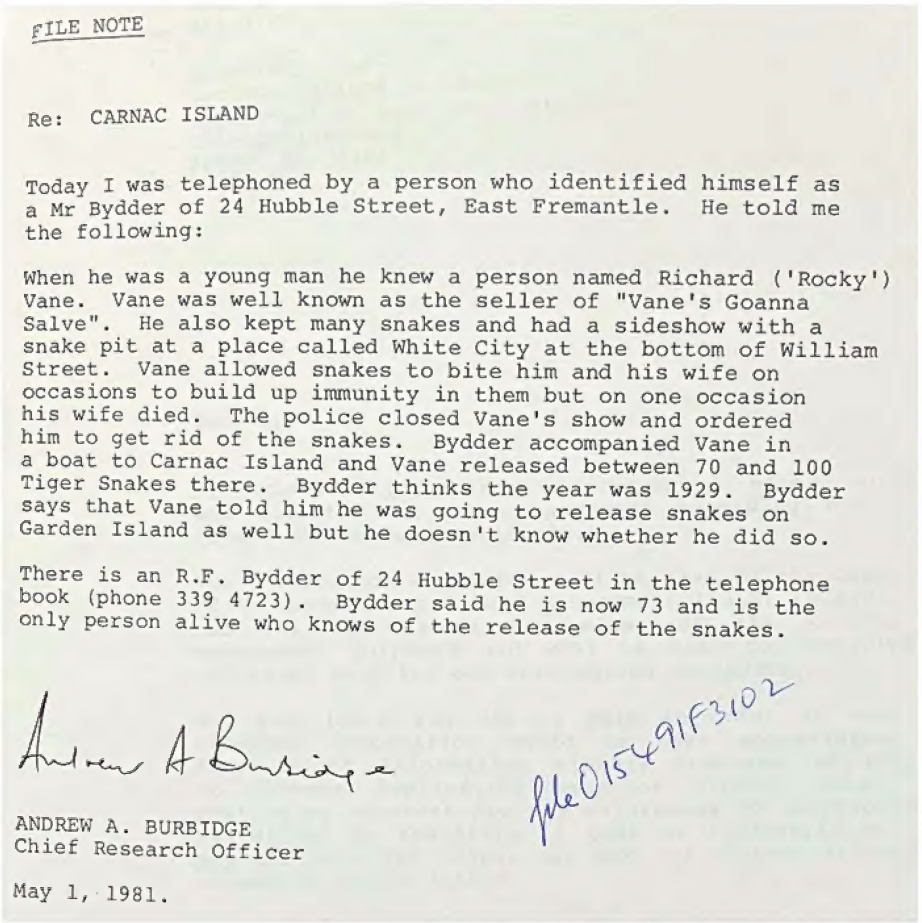
The origin of the population of Tiger Snakes (*Notechis scutatus*) occurring on Carnac Island, a nature reserve off Fremantle, Western Australia, has been a subject of much discussion. Pearson and Bonnet (2007) and Ladyman *et al*. (2020) considered that this island population was established from a small number of snakes released in the early decades of the 20th century. They also concluded that the snakes were released by snake showman Lindsay Vagne, known as Rocky Vane (hereafter Vane) in about 1930. Here I provide additional information about the possible release date, the date of the earliest collection of tiger snakes on the island and additional information from the person who probably helped Vane release the snakes. Although some information about Vane has been published previously, it is worth providing some extra background on him, as it notes his interest in, and presumably a love of, snakes, providing a reason why he would release his snakes rather than kill them, as well as providing the reason why he had to release them.

Ladyman *et al*. (2020) reported the frequent troubles that Vane had with law enforcement authorities in Western Australia and the eastern states and provided information about his shows in the early 20th century. They reported that Vane's first wife died of a snake bite in 1928 and his new partner Harry Melrose was also bitten and died in 1929 (Bonnet & Pearson 2007). At the 5 March 1929 inquest into Melrose's death, the coroner, taking note of that death and alluding to an earlier case, presumably the death of Vane's wife just over a year earlier, recommended that the government shut down all snake shows in the state (*Daily News*, 5 March 1929). The government accepted the recommendation.

Vane must then have had the problem of what to do with his snakes, and when the origin of the Carnac Island Tiger Snakes became a matter of interest in the early 2000s, there was speculation about his possible responsibility (Bonnet *et al*. 2002, 2011; Aubret 2005; Pearson & Bonnet, 2007; Ladyman *et al*. 2020; Bush 2023). That speculation centred partly on a file note the author of this paper, then the Chief Research Officer in the Department of Fisheries and Wildlife in Perth, wrote about a telephone call he had from a person stating he had helped Vane take the snakes to Carnac Island. Thanks to a copy made by Ian Abbott, the relevant file note is shown in Fig. 1. The file note reinforces the earlier views that Vane released Tiger



FILE NOTE

Re: CARNAC ISLAND

Today I was telephoned by a person who identified himself as a Mr Bydder of 24 Hubble Street, East Fremantle. He told me the following:

When he was a young man he knew a person named Richard ('Rocky') Vane. Vane was well known as the seller of "Vane's Goanna Salve". He also kept many snakes and had a sideshow with a snake pit at a place called White City at the bottom of William Street. Vane allowed snakes to bite him and his wife on occasions to build up immunity in them but on one occasion his wife died. The police closed Vane's show and ordered him to get rid of the snakes. Bydder accompanied Vane in a boat to Carnac Island and Vane released between 70 and 100 Tiger Snakes there. Bydder thinks the year was 1929. Bydder says that Vane told him he was going to release snakes on Garden Island as well but he doesn't know whether he did so.

There is an R.F. Bydder of 24 Hubble Street in the telephone book (phone 339 4723). Bydder said he is now 73 and is the only person alive who knows of the release of the snakes.

Andrew A Burbidge

file 015491F3102

ANDREW A. BURBIDGE
Chief Research Officer

May 1, 1981.

Figure 1. Copy of the file note made by Andrew Burbidge after his telephone conversation with the person who helped Rocky Vane transport and release Tiger Snakes on Carnac Island.

Snakes on Carnac Island, but the date is suggested as 1929, rather than 1930. It also suggests that the founder population was in the order of 70 to 100 snakes, rather than the 'some 40' (Ladyman *et al*. 2020, p. 40).

Ladyman *et al*. (2020) reported that 'the earliest records of Tiger Snakes from Carnac Island are in 1982 (Accession Nos R4975, R12818 and R12827), collected by Dr Dom Serventy, Eric Car and Harry Butler respectively, with a large collection by Dr Terry Schwaner in 1985' (p. 41). The first specimen of a Carnac Island Tiger Snake was collected by Dr D.L. (Dom) Serventy (Bush 2023, although he was sceptical of a release origin) on 19 September 1934, although the specimen was not registered until 1982. Serventy's notebook for this date states 'Tiger Snake, Egernia and

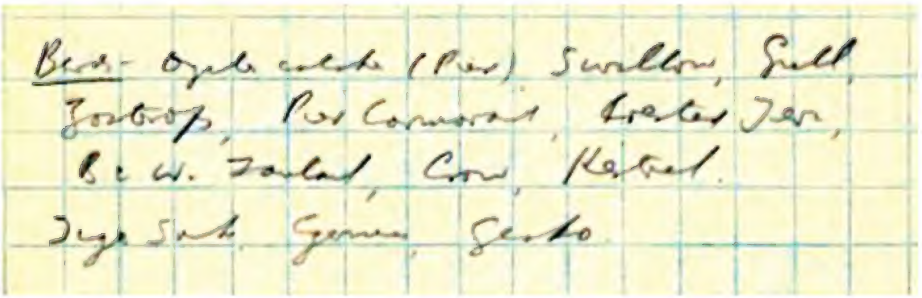


Figure 2. The relevant paragraph in Dom Serventy's notebook entry for 19 September 1934 listing (in the last line): "Tiger Snake, Egernia, Gecko."

Gecko' (Fig. 2). This collection date is soon after the presumed release of Tiger Snakes on Carnac Island in about 1929. The specimen was likely one of those released by Vane or a recent descendent.

Ladyman *et al*. (2020) stated that their research 'revealed the existence of early newspaper and other articles that suggest snakes did not occur naturally on the island' and provided some of these in their paper. The investigation of sources, mainly Trove (https://trove.nla.gov.au/), show that two newspaper articles exist suggesting snakes occurred on Carnac Island before 1930. The first was an 1882 article light-heartedly reporting on a day's rabbit shooting sometime in late September or early October. One participant was reported as saying, 'We had a fine day's sport over at Carnac; but snakes are plentiful over there just now'. The story goes on to tell of an attempt to kill one of the snakes (*Daily News*, 3 October 1882). The second report is of a trip to Carnac Island in March 1914, in which the author noted that 'my mate saw a snake' (*Western Mail*, 20 March 1914). The first article appears somewhat definitive, while the second is anecdotal at best and can be dismissed.

These two newspaper articles do not concur with the many articles and other reports that reported the absence of snakes on Carnac Island before 1930. In 1829, 29 people spent five days on the island after their vessel, the *Parmelia*, ran aground (Pearson & Bonnet 2007; Abbott & Burbidge 2022) and did not report snakes. Furthermore, the reports of early researchers and many others who landed on Carnac make no mention of snakes. For example, in 1909, 30 naturalists spent one night and a day on the island, but no snakes were reported (Abbott & Burbidge 2022). I suggest it is likely that the early newspaper report of snakes were actually of Kings Skinks (*Egernia kingii*), which are common on Carnac Island.

The additional information provided here reinforces the view that the population of Tiger Snakes on Carnac Island originated from a release by snake showman Lindsay Vagne, accompanied by R.F. Bydder, probably in 1929, and that the founder population was probably in the order of 70–100 individual snakes. The weight of evidence is that there were no large snakes on Carnac Island prior to 1929.

Acknowledgements

I thank Ian Abbott for providing his copy of the file note, Paul Doughty for providing information on an early Western Australian Museum specimen of the Tiger Snake on Carnac Island, Wendy Crawford, librarian at the WA Museum, for providing a copy of the relevant pages of Dr Dominic Serventy's notebook and Ian Abbott, Brian Bush and David Pearson for critically reviewing an early draft of this paper. I also thank the reviewers of an earlier draft of this article for their comments.

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From Field and Study

Observations on Striated Pardalotes

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In July 2023, Striated Pardalotes (*Pardalotus striatus*) (Fig. 1) began taking an interest in an artificial nest box made from a gourd attached to a fence in our Kalamunda garden (native shrubs plus several mature, healthy marri trees (*Corymbia calophylla*) nearby). There appeared to be two pairs involved – we often saw three adult birds displaying on or close to the box while a fourth was in a nearby small tree.

In August, we watched birds taking nesting material into the box. We were unable to identify individuals but there still appeared to be two pairs in the garden. Western Little Wattle Birds (*Anthochaera lunulata*)

Figure 1. Adult Striated Pardalote. Photo: R. Green. **Figure 2.** First baby Striated Pardalote ready to fly from the box. Photo: R. Green. **Figure 3.** Pardalotes came out two at a time. Photo: R. Green. **Figure 4.** Fledgling pardalote number 6 unable to fly yet. Photo: R. Green.

constantly harassed them and on 26 August we discovered a dead pardalote apparently having flown into a window. We presumed it had been chased there by a Wattle Bird.

Activity continued throughout September and October. Wattle Bird harassment had ceased by then and on 27 October we observed a chick being fed at the nest entrance. After about 30 minutes it flew out strongly to a nearby tree (Fig. 2). Another chick repeated this behaviour later in the day. The following morning, two more chicks did exactly the same whereupon we were surprised to see the heads of, and photographed, two more chicks still in the nest box (Fig. 3). We saw the fifth chick come to the nest entrance though did not observe it leaving the nest, but the next day we did see the final chick flutter weakly to the ground (Fig. 4). All chicks appeared to disperse eventually – we observed two being fed in a tree for a short time.

According to Johnstone and Storr (2004), the clutch size for striated pardalotes is three to four eggs so for us to observe six fledglings seems surprising. A question arises – were there six eggs in this clutch or were there two clutches in that nest box, the first belonging to the dead pardalote, and a second to the other pair?

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From Field and Study

A new record of the rare White-spotted Ground Gecko *Lucasium alboguttatum* in the Perth region

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Widespread land development has caused significant declines of herpetofauna throughout the Perth region, with few species persisting in the small bushland remnants left in the wake of development (How 1978; How & Dell 1994, 2000). Several species are known from few recent records, raising critical concerns regarding their current statuses within the Perth region (Bush *et al*. 2010).

The White-spotted Ground Gecko (*Lucasium alboguttatum*) is a small nocturnal lizard occupying sandy woodlands and heathlands along the Western Australian coast between Melaleuca and Coral Bay (Wilson & Swan 2013). It is abundant throughout most of its range (Bamford & Calver 2015; Bamford *et al.* 2015), except in the southernmost peripheries – records in the Perth region are therefore of great significance.

On 18 February 2024 at 8:50 pm, we captured an adult *L. alboguttatum* (Fig. 1) active amongst open sandy *Banksia* woodland at Melaleuca Park at 31°40′38.9″S, 115°55′30.6″E. The specimen was immediately identified upon visual inspection, photographed and subsequently released. The habitat was characterised by *Adenanthos cynorum*, *Banksia attenuata*, *B. menziesii*, *Hibbertia hypericoides* and *Xanthorrhoea preissii*, atop pale sandy soils.

The only other record in the Perth region in the past 29 years was also from Melaleuca in 2009 (B. Maryan, pers. comm.). The *Banksia* woodlands throughout Melaleuca are of high conservation importance, owing to their size, connectivity and high vegetation quality. Historically, specimens have also been collected from suburban bushland remnants throughout the metropolitan area (Smith 1985; Turpin 1990, 1991; How *et al*. 2022). However, the absence of recent specimens from these reserves suggests they have been extirpated. Deteriorating habitat quality and increased human disturbance are likely causes, exacerbated by the species' inability to persist indefinitely in small bushland remnants. These extirpated populations were likely first detected upon already becoming functionally extinct.

The Melaleuca population now represents *L. alboguttatum*'s southernmost limit, which was historically the now-extirpated populations at Wireless Hill and Kensington (Smith 1985; Turpin 1990, 1991). However, another population may persist at Whiteman Park, *ca.* 15

Figure 1. *Lucasium albogutattum* at Melaleuca Park. Photo: Forrest He.

km south of Melaleuca. Specimens were recorded in 1986 and 1995 (Arnold *et al.* 1991; Drew 1998) and the excellent habitat quality and size of the reserve may still support a population. The extensive and pristine habitat in that area is ideal for the species.

This *L. alboguttatum* record reinforces the significance of the Melaleuca bushland and verifies the continued persistence of the species in the Perth region, if only with a single population. Further survey work should be undertaken to locate other populations, particularly at historical collection sites. Recent survey work has recorded many species in unexpected habitats and regions for the first time (Algaba 2005; Davis & Bamford 2005; Davis & Wilcox 2008; Maryan & Algaba 2011; Thompson *et al.* 2008).

Acknowledgements

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From Field and Study

First Australian mainland specimen of Nicobar Pigeon *Caloenas nicobarica*

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The first report of the Nicobar Pigeon (*Caloenas nicobarica*) for the Australian region comes from a Polaroid photograph taken by Raymond Nojek of an immature bird that landed on the Jabiru Venture (an oil rig in Timor Sea [north of the Kimberley, Western Australia] at 11°55'33"S, 125°00'23"E) after a storm in February 1989 (Johnstone & Storr 1998). It remained onboard from 1300 hrs until mid-morning the next day (see Fig. 1). This sighting was accepted by the Birds Australia Rarities Committee (BARC Case 836).

This note relates to a bird captured in 2017 at One Arm Point on the Dampier Peninsula, Western Australia (Collins and Mills 2017; Kimberley Land Council 2017). In April 2017, a strange pigeon was seen walking across a road near a monsoon vine forest patch at Chile Creek on the northern Dampier Peninsular. Several other sightings followed and in early May a juvenile bird was captured by children in the garden of a house at One Arm Point about 20 km north of the Chile Creek site, near the northern tip of Dampier Peninsular.

The pigeon was identified from photographs as a Nicobar Pigeon and as it posed a potential biosecurity risk, the Department of Agriculture and Food WA (DAFWA) was contacted. Phillip McCarthy, the Bardi Jawi Ranger Co-ordinator, arranged for the bird to be collected by James Mathews of DAFWA, and then arranged for it to be airfreighted to Perth where it was to be held in the DAFWA's South Perth quarantine aviaries. As the Perth Zoological Gardens did not have any Nicobar Pigeons in its collection, it was decided to send the bird to the Adelaide Zoo under the condition that when it died it would be repatriated back to Western Australia and then to the Western Australian Museum as it represented the first mainland specimen of this rare species. The bird suffered a leg injury and was euthanised on 17 September 2023, frozen and returned to the Western Australian Museum where it was prepared into a study skin (registered number A48187). It was identified as the nominate subspecies *C. n. nicobarica,* based mainly on its size (it is larger than *C. n. pelewensis*) and longer hackles.

Details of the deceased bird from the Adelaide Zoo (in breeding condition) are as follows: adult male, testes 22.2 x 8.6 mm; total length 384 mm; weight 600 g; exposed culmen 21 mm (to

Figure 1. Nicobar Pigeon on board the Jabiru Venture. From a photograph by Raymond Nojek with digital enhancement by R. Fleming.

edge of cere); entire culmen 34 mm; wing 265 mm; tail 90 mm; tarsus 47 mm; middle toe and claw 54 mm. Iris dark brown; bill black with enlarged cere; mouth reddish; legs and feet dull reddish brown. Head, neck and upper breast, blue-black with long (up to 113 mm long) dark metallic green and copper neck hackles, some with a silver purple bloom, that extend across the mantle. Primaries and secondaries dark blue glossed with green and purple and inner webs blackish. Belly mostly dark iridescent green and blue. Tail and undertail coverts white (Figs. 2, 3).

Of interest is that when the pigeon was originally captured and photographed, it was in juvenile plumage with short hackles and a black tail. Juveniles and immatures lack the

Figure 2. Dorsal view, Nicobar Pigeon - WA Museum A48187. Photo: K. Sarti.

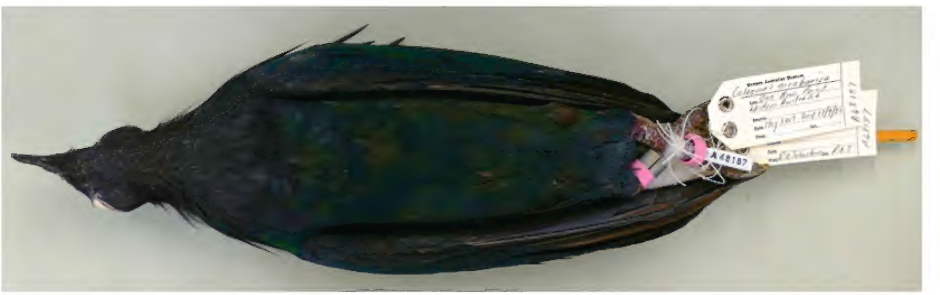

Figure 3. Ventral view, Nicobar Pigeon - WA Museum A48187. Photo: K. Sarti.

neck hackles and are entirely brownish black, including the tail and the hackles are acquired before the white tail. This is of interest because the bird photographed on the Jabiru Venture and the One Arm Point specimen were both juveniles possibly indicating that juveniles and immatures may disperse more than adults (White & Bruce 1986).

The Nicobar Pigeon occurs across the Indo-Australasian region from the Andaman and Nicobar Islands, the Mergui Archipelago, small islands off Malay Peninsula, the Con Son Islands (off South Vietnam) through Indonesia and Philippines to islands off New Guinea and Solomon Islands (Del Hoyo *et al.* 1997).

The population on the Palau Islands in the western Pacific Ocean is treated as the separate subspecies *C. n. pelewensis* based on their slightly smaller size (length 280 mm [11 inches] and wing 228 mm [9 inches]), shorter neck hackles some bifurcated at tip and overall bluer plumage (Salvadori 1893). This population is considered vulnerable by the US Fish and Wildlife Service, although numbers are apparently stable at present (Del Hoyo *et al.* 1997).

The Nicobar Pigeon is well known as a bird of islands, but even in an archipelago of small islands it favours only the smallest unless they are arid or lack forest. It generally occurs on small, wooded islands with mangroves and lowland and secondary forests. It forages mainly on the ground on fallen fruits and seeds and is particularly active at dawn and dusk. Its thick-walled muscular gizzard, which is lined with horny plates, can grind nuts that require a hammer to break (Coates 1985). *Caloenas* is a distinctive genus and recent DNA evidence has revealed that it is the closest living relative to the extinct Dodo (Shapiro *et al*. 2002).

The species is highly nomadic, moving between islands and often visiting larger islands, e.g. New Guinea when and where certain trees are fruiting. Occurs singly and in pairs, occasionally flocks up to 85 (Del Hoyo *et al*. 1997). Locally common but appears to have declined markedly over much of its range including the Indonesian Archipelago. It is now considered rare through much of the Greater Sundas. In the Lesser Sundas the closest islands to Western Australia, they are recorded from Lombok, Satonda, Sumbawa, Komodo, Padar and Rinca. The latter islands are the most likely region of origin of this bird. It is listed as 'Near Threatened' in the BirdLife International (2023) IUCN Red List for birds.

Acknowledgements

I thank Kim Sarti for editorial comments on earlier drafts of the manuscript and help with photographs. Robert Fleming helped enhance the old Jabiru Venture photograph. I also thank members of the Bardi Jawi community for providing details of the discovery of the bird and Win Kirkpatrick (DAFWA) for organising its shipment to Perth and help with its return from Adelaide Zoological Gardens.

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From Field and Study

Eastern Australian *Kunzea* (Myrtaceae) species: potential serious environmental weeds in Western Australia?

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Kunzea is a medium sized genus of approximately 44 species occurring in Australia and New Zealand, of which 26 species are confined to Western Australia (WA) (Sainsbury 2019). Many members of the genus are highly ornamental (Elliot *et al.* 1992), used in the manufacture of therapeutic oils (*K. ambigua* (Sm.) Druce, kanuka) or bush foods (*K. pomifera* F. Muell., muntries/muntjes). The very closely related genus *Leptospermum*, especially *L. scoparium* J.R. Forst. & G. Forst. from eastern Australia and New Zealand is used in the production of manuka honey. Currently there are efforts to produce a range of honeys with specific compounds from *Kunzea* especially *K. ambigua*. Therefore, there is a growing interest in cultivating non-indigenous members of the genus in WA. The purpose of this short note is to raise awareness of potential of some species becoming very serious environmental weeds in WA.

All species of the genus *Kunzea* not native to WA are permitted to enter WA (Western Australian Organisms List 2024) as seeds, cuttings or plants without any restrictions. Since the genus, having either no records or little history of naturalisation at the time of compilation of the permitted list (Randall 2002), members were perceived as low risk to the environment or agriculture in WA.

Is this low risk assessment still valid?

It is known that members of the genus demonstrate a number of known undesirable traits, which aid species to establish beyond cultivation and assist the path to naturalisation (Global Invasive Species Database 2020). These traits are:

- Members are possibly naturalised outside native range. Other species or close relatives (i.e. *Leptospermum*) are known to be invasive;
- Many species are colonisers and form dense stands;
- Many species tolerate a range of soil types;
- Many species have ready access to local mycorrhizal fungi and can grow in nutrient poor soils;
- Most species produce abundant seed;
- Seeds dispersal is variable (wind, animals, water, people);

- May have persistent canopy seed bank;
- Variable life histories, some species spread vegetatively, including, *Kunzea ericoides* (A. Rich) J. Thomps., *K. micrantha* Schau and *K. pomifera*, some species resprout and some are obligate seeders;
- Bird dispersed fruits are common;
- Rapid maturity (<4 years);
- Plants are then relatively long lived giving very high seed output.

These traits increase the levels of risk in a weed risk assessment (Global Invasive Species Database 2020). Several of these traits greatly increase the potential to become weedy in WA and are considered in more detail.

Members are naturalised outside their native range and invasive. Eastern Australian species can behave as weeds in a similar climate to WA. In Victoria (Vic) Carr (2001) listed the Victorian natives, *K. ambigua* and *K. ericoides* as two of the 20 most serious environmental weeds in Victoria because both were "ecologically out of balance". The species becoming structurally dominant in natural stands despite being a minor component before, and expanding their ranges into adjoining vegetation types. They also were being introduced into areas outside their natural range and aggressively invading bushland in these areas. In New South Wales (NSW) and Vic native *Kunzea* species can be treated as weeds under the New South Wales Biodiversity Act 2016 in these areas as part of a biodiversity management plan because of these tendencies.

Members of the genus are known to be aggressive colonizers of natural habitats after disturbance, often creating a monoculture as an understory of woodlands. This occurs after grazing and partial clearance in eastern Australia, e.g. violet kunzea, *K. parvifolia* Schau, in NSW (Kennett *et al.* 2011). In WA, we have observed both *K. glabrescens* Toelken and *K. ericifolia* (Sm.) Heyhn. dominating banksia woodlands after dieback disease, partial clearing, grazing or frequent fires.

Therefore, it appears that the potential for *Kunzea* species to act as invasive weeds is present in several species. This should be reflected in a current weed risk assessment before members of the genus were allowed to be imported into WA.

The other major risk factor is observations on naturalization records for members of the genus, both outside and within WA. Following extensive literature searches we have noted the following records.

Kunzea ambigua, an eastern Australian species was first recorded on road verges around Albany in 2012. Then the species was located on road verges north of Cheyne's Beach. Subsequently very large populations have been recorded in Manypeaks town site and under tree plantations near Cheyne's Beach (K. Bradbury, *pers. comm.*). This appears to be potentially a very invasive species of wetlands from Augusta to Bremer Bay. This species should be removed whenever seen and not planted in WA. This species occurs in very large dense stands after fire and can dominate the understory. This species has a series of records on its invasive nature noted previously in eastern Australia (see above).

Kunzea baxteri (Klotzch.) Schau., a very ornamental species has been widely planted in WA outside its

native range which is between Cape le Grande and Daw Island, east of Esperance, and this has resulted in numerous naturalisedferal populations. Planted around the Bluff Knoll carpark in 1960s subsequent dieback and fire impacts on surrounding vegetation have led to the establishment of a large naturalisedferal population downslope. The species was widely planted as part of reafforestation/rehabilitation efforts in the northern jarrah forest and is now a common roadside weed from Dwellingup to north of Jarrahdale. Scattered self-perpetuating populations have been recorded along road verges from Walyunga to Bremer Bay (Keighery 2013).

Kunzea ericoides is a species complex that remains to be resolved. Considered to either confined to New Zealand, as a species complex, where up to 10 species have been discriminated, or as part of a widespread and variable New Zealand and eastern Australian species, or finally as a series of species with true *K. ericoides* confined to New Zealand. The Australian component(s) are segregated as *K. leptospermoides* F. Muell. Ex Miq. (native to eastern Vic and NSW, Yarra burgan), *K. peduncularis* F. Muell. (Victoria, mountain burgan) and *K. phylicoides* (A. Cunn. ex Schau.) Druce (Australian Capital Territory (ACT), NSW and Vic., slender burgan), but the taxonomy is still fluid. Members of the Australian component of the complex have been recorded as a weed in the ACT and Tasmania and beyond the species complex native range in Vic. Recorded as naturalising in Hawaii on the island of Lanai from New Zealand plants (CABI Compendium 2019; Imada 2019). In Vic a member of this complex, *K. leptospermoides*, is becoming a serious weed in the Grampians (Friends of Grampians 2021). A member of this complex is naturalised on road verges between Manjimup and Walpole in WA, its exact origin is unknown, but it is probably a form of *K. leptospermoides*.

Kunzea flavescens C.T. White & W.D. Frances, a Queensland species was establishing naturalisedferal populations on Black Mountain in the ACT, before all plants were removed (Purdie 2014).

In eastern Australia *K. pomifera* is locally naturalised in Tasmania (Barker 2005) and at Jervis Bay (ACT-Cape Jervis Community Group 2013). This species native to coastal South Australia and Vic is being widely cultivated and further naturalised records are expected.

Despite having little history of weediness before 2000 (Randall 2002, 2017), searches of the "grey" literature reveal instances of the weedy to invasive nature of many commonly cultivated species. This search also reveals the need for authorities (libraries or State archives) to document/archive the great management activities of such groups in readily accessible formats, often as these are the first records of spread into bushland of many weeds. Many of the newsletters of friends groups are not preserved or able to be accessed because there is no formal need to preserve them.

The ecological impact of invasive *Kunzea* species is very poorly documented, but in the Grampians, dense stands non-native *Kunzea* are displacing native species. *Kunzea* species also readily hybridise, both in the wild and cultivation (Sainsbury 2019; Toelken 2016), including very broad crosses to *Leptospermum* (Harris *et al.* 1992). This is another risk factor

to be considered in an area rich in native species. The beginnings of widespread naturalization of several eastern Australian species of *Kunzea* (*K. ambigua* and *K. ericifolia* complex) in WA in areas rich in local native species of the same genus is potentially very serious. The Shire of Manjimup for example has nine native taxa of *Kunzea* and the Shire of Albany has 11. This may pose a long-term threat to several localised native species from displacement via competition and hybridization.

In conclusion, we recommend that eastern Australian species of *Kunzea* should not be promoted, sold or used as garden plants in WA to lessen the risk of widespread naturalisation. A large number of attractive WA native species are available to use instead, with less weed risk (Randall 2017; Sainsbury 2019).

Members of the genus from areas outside of WA should be removed from the permitted list and have a weed risk assessment undertaken before being allowed back on the permitted list. Any proposal to commercially cultivate non-native *Kunzea* or *Leptospermum* species for oils or honey in WA, especially near bushland needs strict bio-security measures.

It may be too late to completely eradicate current naturalised populations, but containment and removal of small infestations to limit spread and their long- term effects should be a priority.

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From Field and Study

Aphids and insectivorous birds

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I have a potted *Duranta repens* (the common blue-flowered variety) that is growing vigorously at present (March 2024). When I looked more closely I saw that the undersides of the young leaves and green parts of the stems supporting them were covered in the common bluegreen aphid (*Acyrthosiphon kondoi*, Hemiptera). A few days later I noticed Grey-breasted White-eyes (*Zosterops lateralis*, an omnivorous, white-eyed bird) working vigorously over the huge parent tree (6 m tall by 7 m wide) outside my unit. I realised that the parent plant must also have aphids and that the birds were harvesting them. After about an hour they departed – "elegant sufficiency" might be the appropriate term, but some have been returning in successive days over the last two weeks (March–April). I have now seen New Holland Honeyeaters (*Phylidonyris novaehollandiae*), Singing Honeyeaters (*Gavicalis virescens*) and, rarely, the Red Wattlebird (*Anthochaera carunculata*) visiting the tree to glean aphids. All birds were also occasionally probing the tiny flowers for nectar. I looked at the new growth on the tree and only tiny nymphs were present. I put the potted plant beside the water bath (the reason I get so many bird visitors) and after I few days I noticed it now possessed few aphids. A brochure from the WA Department of Primary Industries and Regional Development (https://www.agric.wa.gov.au/control-methods/aphids-mealybugs-and-scales) noted the value of ladybirds, hoverflies, parasitic wasps and lacewings in their control, but no mention of the far more effective birds that would take scores with each glean. There is a message here – when next you notice an infestation of aphids on your prized plants, instead of running for the insecticide, place a water bath among your shrubs instead! Admittedly, it took 12 months before birds started visiting my bath, but now they can't live without it, and it is a joy to watch them frolicking.

From Field and Study

An additional record of Frilled Lizard (*Chlamydosaurus kingii*) from south of the Roebuck Plains, Western Australia

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The Frilled Lizard (*Chlamydosaurus kingii*) is a large iconic agamid with an extensive distribution in tropical woodlands extending east from Broome in the western Kimberley through the northern Northern Territory (NT) to western Queensland and then from the top of Cape York Peninsula south to the Brisbane area (Melville & Wilson 2019), apparently in association with the forested Great Dividing Range. It also occurs in southern New Guinea (Cogger 2018; OZCAM 2024).

On 20 January 2024 at about 8 am, while travelling on the Great Northern Highway (GNH), one of us (CL) observed a Frilled Lizard (Fig. 1) on the road 5.5 km SSW of the Goldwire 24-Hour Rest Area (-18.6432°, 121.9427°), and 82.5 km SSW of Broome. The temperature was approximately 29°C, the humidity 67% and the sky was primarily overcast with small intermittent patches of blue showing through the clouds.

A check on OZCAM suggests there are no museum records in Western Australia (WA) south of a line from Broome (-17.9618°) east through Mount Anderson homestead (-18.0333°), Halls Creek (-18.1337°) and 30 km north of Nicholson homestead (-17.4003°) just west of the NT border. Bush (1985) reported the occurrence of this lizard slightly further south (-18.2503°) of this line in the western Kimberley when he stated that those he sighted were distributed: "… 20 kilometres northeast of Broome to 60 kilometres south of the Broome-GNH junction (to lat. 18°15'S)" (p. 53). However, the distances mentioned in his brief note were not in a straight line but recorded by road on his vehicle's trip meter. Therefore, the Broome Road junction to latitude 18°15'S is only about 44.4 km, well short of the 60 km he mentions. Furthermore, he added: "Only one of the eleven lizards observed was south of the Roebuck Plains" (p. 53).

Now, 40 years later, with the assistance of Google Earth Pro we have localised his observation of the one individual to the GNH 1.6 km SSW of the north access road to Thangoo Station, 37 km SSE of Broome or, in a straight line 14.4 km south of the Roebuck Plains.

Between 30 January and 5 February 2024, Chris Mitchell on our behalf requested additional anecdotal observations of these lizards by local residents on Facebook page

Figure 1. Frilled Lizard (*Chlamydosaurus kingii*) photographed on Great Northern Highway 82.5 km SSW of Broome, WA. Photo: C. Lehmann.

Broome's Natural Environment. We also sent similar requests by email to the Department of Biodiversity Conservation and Attractions, Barn Hill Station Stay, Shamrock Station and through a live broadcast with Andrew Collins on radio station ABC Statewide Drive. This resulted in the following list of localities where these lizards have been seen south of the Roebuck Plains: Eco Beach (2 respondents), Port Smith (2), Shamrock Station (1) and widespread in the general area (1). Except for the last mentioned, all these localities share an abundance of large well-established trees making them ideal localised habitats for this large arboreal lizard. Its apparent scarcity over much of the remaining area of pindan south of the Roebuck Plains is probably associated with the lack of large trees in the *Acacia*-dominated shrublands.

It was reported by one of our respondents that these dragons would appear to "come and go" at Port Smith; however, we believe this was an impression caused by the seasonal shift in this species' behaviour: it is frequently seen during the monsoonal months when active on the ground or close to the ground when perched on the bottom portion of the tree trunks to heights of 2 m, and then unsighted during the dry season when inactive and aestivating high up in the canopy at the tops of the trees (Melville & Wilson 2019).

With this being only the first published observation of a Frilled Lizard south of the Roebuck Plains since that of Bush (1985), local surveys in the area are needed away from the highway to determine both its actual abundance in this southwestern part of its range and if these records represent accidental localised introductions. However, the latter appears unlikely as one could expect more reports of this species from much further south well outside its natural range including in the Perth metropolitan area.

Acknowledgement

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From Field and Study

First record of Beaton's club (*Geomorium beatonii*) from Western Australia

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The Ascomycete fungus *Geomorium beatonii* (= *Underwoodia beatonii*), Beaton's club, is known only from Australia. It is uncommon, having only been collected from South Australia and Victoria (Grey & Grey 2005). A new collection was made in August 2023, at Morangup (-31.6705°, 116.2906°), approximately 80 km northeast of Perth (Fig. 1). It was growing in gravel under an overstorey of *Eucalyptus marginata* and *Melaleuca* spp., with an understorey dominated by *Banksia* spp. and *Hakea* spp. There were two fused clusters of waxy, fleshy, sooty brown, irregularly grooved round-tipped spears which had emerged from the gravelly soil. The spears were up to 97 × 22 mm, the blunt tips were up to 11 mm wide. The upper third of the spears were brown, the lower two-thirds were creamy with no demarcation between the regions (Fig. 2). The surface of the spears lacked hairs and were waxy and dry to the touch. A longitudinal section through the spears showed irregular cavities which were smaller and more irregularly arranged at the tip.

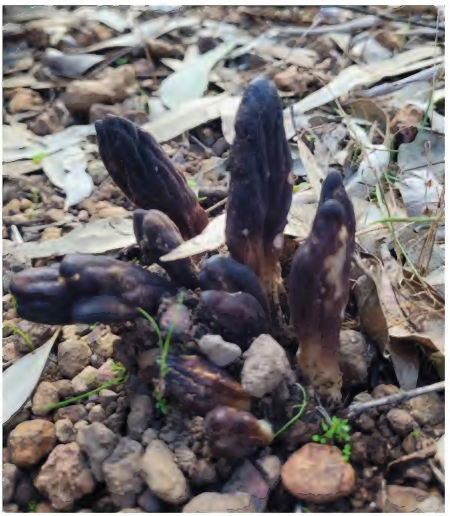

Figure 1. *Geomorium beatonii* in the field. Photo: L.E. McGurk.

Microscopic examination shows asci that are cylindrical over most of their length but with slightly rounded tips and tapered bases, 236–296 × 20–24 μm (Fig. 3). The paraphyses are long, 4–6 μm wide, septate, occasionally anastomosing at the base, the tips, 6–10 μm wide, are mainly clavate but also irregular or forked, and most tips have granular contents. The paraphyses project up to 36 μm beyond the asci. The ascospores are uniseriate, ellipsoidal, with a thickened finely verrucose wall. Each ascus contains eight spores.

The collection has been provisionally identified as *Geomorium beatonii*, this needs to be confirmed by DNA analysis. This collection is an exciting addition to the distribution

Figure 2. *Geomorium beatonii* ascocarps, collection 2023-02 LEM. Photo: L.E. McGurk.

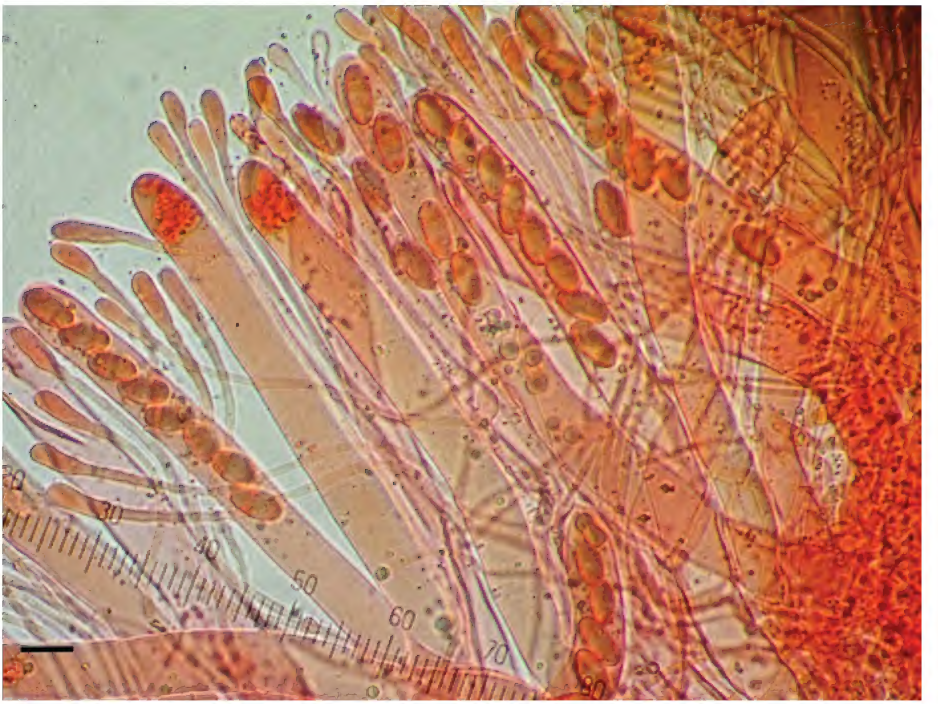

Figure 3. Asci and paraphyses of *Geomorium beatonii*, stained with Congo red. Scale bar is 10 μm. Photo: L.E. McGurk.

of Australian fungi and to West Australian fungal diversity. Please keep your eyes out for this distinctive fungus. It would be wonderful to find more.

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From Field and Study

White-bellied Sea-Eagle breeding sites in southwest Western Australia

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Most of the Australian White-bellied Sea-Eagle (*Haliaeetus leucogaster*) population is located in the north of Australia, in warm-temperate and tropical coastal regions where there are substantial rivers, and broad freshwater or estuarine wetland habitats (Marchant & Higgins 1993; Dennis & Detmar 2018). In Western Australia (WA), they breed almost exclusively on islands; for example, there are an estimated 25 breeding pairs on the Houtman Abrolhos (Storr 1991; Surman & Nicholson 2009; Johnstone & Coate 2023). They are known to occur inland where suitable habitat exists, such as Lake Argyle.

Mainland breeding records in the southwest of WA are scarce and their breeding distribution in this region is poorly known. Serventy and Whittell (1976) mention "they appear to be rather rare around the southwest corner of WA". Johnstone and Storr (1998) state that there are breeding sites at the Peel and Wilson Inlets, but not between.

My aim is to provide an update on the number of known mainland White-bellied Sea-Eagle nesting sites in the southwest of WA between Perth and Albany (Fig. 1). Exact locations are not given because the birds are sensitive to

Figure 1. Map showing nesting sites of White-bellied Sea-Eagles in the southwest of Western Australia. Yellow markers are active nests and red markers are suspected nests.

disturbance (Dennis & Detmar 2018); there may be additional nest sites within this area. Offshore islands are not included.

Volunteers monitored the nesting sites during 2023, recording the status of the site, breeding details, number of fledglings, behaviour and prey selection. Known historical information, if available, is included for the sites. Fourteen nests and four possible nests were identified. The number of visits varied from weekly to a few visits during the breeding season. Monitoring was done from a distance to minimise disturbance (Department for Environment and Water 2022).

Lake Joondalup

There is a nest on Lake Island in Lake Joondalup, which can be seen from the north end of Picnic Cove, in a large paperbark tree about 6 m high. They have been seen around this site for about three years and are often seen hunting Australian White Ibis at the northern end of Lake Joondalup. The lake has a rich water bird population as well as ample European Carp.

White-bellied Sea-Eagles raised their first juvenile during the 2022 season. Both adults were seen next to the nest in April 2023 and were nest-building and mating in early May. The incubation period is estimated to have started in early June. There were two nestlings in the 2023 season though one was lost due to high winds in early September (P. Snow, pers. comm.). The nestling took its first short flight around mid-October and took short flights to and from the nest on 6 November. In late January 2024, the male White-bellied Sea-Eagle had been absent for some months though the female, last year's immature (2022) and this season's juvenile (2023) were seen regularly.

Baldivis, Kerosene Lane

There are two White-bellied Sea-Eagle nests at Kerosene Lane, Baldivis. The old and the new nests are located on opposite sides of Kerosene Lane about 100 m apart. The active nest is on private property, 50 m from the road to the north of Kerosene Lane and has been in use since at least 2019. It is an imposing structure situated high in a large tuart (*Eucalyptus gomphocephala*) tree, surrounded by gum trees and smaller vegetation. The old vacant White-bellied Sea-Eagle nest is on the southern side of Kerosene Lane about 30 m from the road, directly opposite the eastern end of the Quarry. It is also in a large tuart tree. These nests are about 6.5 km from the Lake Walyungup site.

One nestling was raised successfully in 2021 and two in 2022 (P. Snow, pers. comm.). On 2 November 2023, two chicks were in the nest with the adult female. On 14 December one large nestling was on the nest exercising wings, and the nest was vacant on 28 December. This pair may be ones that are frequently seen at Wellard Wetlands, 1.5 km away, which has a rich waterbird population. The Kerosene Lane site is threatened by encroaching housing developments.

Warnbro, Lake Walyungup

There is a record of White-bellied Sea-Eagles nesting in Baldivis Children's Forest on 27 June 2008 in a large tree near the reserve boundary (J. Tregonning, pers. comm.). However, a branch fell across this nest and the birds moved to a new location.

White-bellied Sea-Eagles currently breed at Lake Walyungup not far from their old nest site in Baldivis Children's Forest. The large active nest is about 50 m from the road, in a tree fork and near the edge of the lake. This nest has been used since at least 2020 when two juveniles fledged. Two juveniles had fledged on 5 November 2021, and there were nestlings in 2022.

In 2023, one adult was perched near the nest on 29 May and 20 June. On 23 August, one bird was sitting low in the nest with the head just showing. Incubation is estimated to have started in late July. The first sighting of a chick was on 18 October; it was mottled dark grey, but largely covered in white down with some primary feathers visible at the end of its wings and was estimated to be five weeks old. On 2 November, a chick was standing on the nest edge, while on 14 December one nestling was sitting low in the nest with an adult on guard roost next to the nest. A juvenile was standing on a branch above the nest on 28 December.

Birchmont, Lake McLarty

White-bellied Sea-Eagles have bred at Lake McLarty in the past and they are still frequent visitors to this lake which is seasonally rich in waterfowl. They used two different nesting sites on the western side of the lake (Craig *et al.* 2018). The first was just outside the nature reserve in tuart on the ridge between Lake McLarty and the Peel-Harvey estuary. The second nesting site was in a large tuart tree near the corner of Kangaroo Loop.

The first recorded breeding was in October 1984 (Storr & Johnstone 1988). On 29 April 2001, a White-bellied Sea-Eagle was seen swooping down, grabbing and breaking off a dead branch from the top of a tree and then carrying the nesting material away. Two adults and a recently fledged juvenile were sighted in December 2001 (Davis 2002). A White-bellied Sea-Eagle was seen next to a nest on 14 October 2002, 16 September 2003 and 11 July 2005. On 25 July 2017, a White-bellied Sea-Eagle was seen bathing in a shallow water pool in the middle of Lake McLarty. Residential development around their nesting trees may be why they left this location (Department for Environment and Water 2022).

Coodanup, Serpentine River

There was an active White-bellied Sea-Eagle nest in 2014–2015, at the corner of Fishhawk Road and Osprey Link, Stake Hill, at the upper reaches of the Serpentine River. There is an active nest at Frasers Landing, near a tributary of the Serpentine River in a tall tuart tree. This nest had one juvenile in December 2021. On 29 October 2023, a White-bellied Sea-Eagle was observed on a branch near the nest (Fig. 2).

Figure 2. Adult White-bellied Sea-Eagle on perch at Mandurah. Photo: Marcus Singor.

There were two juveniles on the nest and one adult circling over the river on 19 November, and on 30 November there were two juveniles on the nest with the two adults nearby. Two large juveniles were standing on the nest on 18 December which was vacant on 27 December; however, the juveniles were still in the vicinity of the nesting site towards the end of January 2024. Extensive land clearing and housing developments are taking place next to this location.

Harvey Estuary, Island Point

There are two White-bellied Sea-Eagle nests on private property near Island Point, Harvey Estuary. They are within sight of each other and have been used and built by the resident pair. The oldest nest is in the fork of dead branches, at the top of a large tuart tree. The new nest, about 200 m from the old nest, was built in 2021. It is high up and sheltered by the surrounding tree canopy. The original nest site has been active since at least 2016 when the pair raised one fledgling. One juvenile was raised in 2020, one in 2021 and one in 2022 when the chick was first sighted at the end of August.

In July/August 2023, White-bellied Sea-Eagles were visiting both nests, and the incubation period is estimated to have started in late July/early August. One chick was visible on 20 October. By 10 November the juvenile was standing on the nest and feeding itself with delivered food. On 8 December the juvenile was out of the nest and making short flights. On two occasions it flew down to the ground to collect prey which may have been deposited by the adults who were both in attendance. The juvenile was often seen near the nesting site throughout January 2024. The White-bellied Sea-Eagles here have encounters with the local Ospreys (*Pandion haliaetus*) which nest nearby.

Bunbury

The White-bellied Sea-Eagle nest at Bunbury is found along the Brunswick River and adjacent to a Great Cormorant (*Phalacrocorax carbo*) colony. The nest is located 15 m high in a 25 m high tuart tree. A bird was seen carrying sticks to the nest in early August 2020 when it was thought to be breeding. Over the 2021 and 2022 seasons, only one chick fledged (R. Peterson, pers. comm.).

A White-bellied Sea-Eagle was sitting on the nest in early July 2023. In the following months, the male regularly returned to that area with prey. On 30 October, the nest was empty.

Capel

There is a White-bellied Sea-Eagle nest located along the Capel River about 2 km inland from the ocean, near Stirling Estate. The pair had two nestlings in 2023. Recently, a fledged juvenile was sighted on 30 December 2023 along the Capel River.

Busselton (1): Reinscourt

A White-bellied Sea-Eagle nest is located on private property adjacent to the Vasse Estuary. This nest is located 1.5 km from the Layman Road site (see below) in a tuart tree. According to the property owner, they have been there for five years.

The nest was active in 2022, and adults were feeding a chick. In 2023 a pair were in the nesting tree on 7 May. The incubation period is estimated to have started in mid-July. One large

Figure 3. First-year White-bellied Sea-Eagle at Busselton, just fledged. Note the black tail band. Photo: Alicia Doyle.

nestling was visible in the nest on 10 October, stretching its wings and partially feathered; an adult dropped food off at the nest and then joined the other adult in a nearby tree. On 25 October two adults were standing in a tree about 50–70 m away while the nestling was standing up straight in the nest. On 19 November the nestling was seen stretching wings on the nest. On 26 November the nestling was standing outside of the nest and flew two circuits around the nest before returning to a nearby branch (Fig. 3). There were turtle shells underneath the tree.

Busselton (2): Nash

There is a White-bellied Sea-Eagle nest located near the Broadwater Nature Reserve, Busselton, 13 km from the Reinscourt site. The nest is in a paddock, in a large, free-standing marri tree, well camouflaged and at about 2/3 of the tree height. It has been there for at least 10 years. The remnants of turtles have been found beneath the tree in previous years.

White-bellied Sea-Eagles roost near the nest and were seen mating on the nest on 4 May 2023. A check on 30 July saw one adult sitting in the tree next to the nest. Further visits were made on 18 August, 16 September, 26 September and 2 October but no White-bellied Sea-Eagles were seen.

The land was cleared in November 2023 removing old tree stumps and vegetation but leaving the large trees standing. The site has been zoned for residential blocks (Department for Environment and Water 2022).

Busselton (3): Layman Road

The White-bellied Sea-Eagle nest is located 180 m from Malbup hide carpark towards Tuart Drive, parallel to Layman Road. The nest is in a tuart tree, but the tree's height makes it hard to know when they are present.

On 15 August 2023, a White-bellied Sea-Eagle flew in and perched on a dead branch near the nest tree. There was one adult already on the nest. The incubation period is estimated to have started in early August. On 16 August an adult looked out of the nest and flew off; both adults were circling, and one quickly approached and entered the nest. On 26 September both adult birds were on the nest calling. On 17 November 2023, two large juveniles were standing in the nest. On 2 December one nestling was on the edge of the nest doing wing stretches. On 12 December a nestling was standing on a branch outside the nest but returned to the nest when an adult returned.

Walpole

There is a nest at Nornalup Inlet, near Rocky Point. The nest is well hidden among trees. One juvenile fledged in 2021. On 1 January 2023, an adult and two fledged juveniles were seen

Figure 4. Adult White-bellied Sea-Eagle in flight at Walpole. Photo: Philippa Beckerling.

at Walpole. The site was checked on 16 October 2023, but no activity was noticed (Fig. 4).

Denmark

A White-bellied Sea-Eagle nest is located near the Rudyard Beach Nature Reserve, 5 km east of Denmark. The nest is in a 15 m high karri tree on private property. There is an island in Wilson Inlet, close to this nest, and juveniles have been sighted here in previous years. A professional fisherman reported an immature bird around his boat while he was pulling in his nets in the inlet. There is a large Pied Cormorant (*Phalacrocorax varius*) colony on a nearby island.

In the second week in November 2019, nestlings were ready to fledge and were standing on the edge of the nest. Two juveniles were sighted in October 2020. Two adults were at the nest on 24 July 2022 and two juveniles were seen in the nest around mid-October 2022, close to flying.

In 2023 first and second-year juveniles were seen around the Inlet (P. Burgess, pers. comm.). During mid-September, both adults were present at the nest site though at other times only one adult was there. The other adult might have been in the nest cup. On 13 October two adults were at Karri Point, Wilson Inlet. The nest was checked on 18 November and one adult was perched nearby with no sign of juveniles. It was concluded that they did not breed successfully in 2023, although adults were seen around the nesting site.

Albany, Two Peoples Bay National Park

There is a White-bellied Sea-Eagle nest located in Two Peoples Bay Nature Reserve, between the visitor and research centre. It has been there for a considerable time. The large nest is in a tree near the stream that runs from Lake Gardner, behind the foredunes and flows across the beach into the south end of Two Peoples Bay. There was a juvenile in the nest in spring 2023.

Albany, Waychinicup National Park

There is a White-bellied Sea-Eagle nest about a kilometre upriver from the Waychinicup Inlet, on the eastern side of the Waychinicup River. In December 2023, one juvenile was reported in the nest.

Suspected nesting locations

Augusta

White-bellied Sea-Eagles have been sighted regularly around the Hardy Inlet over the past five years. Juvenile birds were sighted in September and October 2022. They are likely to breed here, although the location is unknown.

Donnelly River

White-bellied Sea-Eagles are regularly seen at the mouth of the Donnelly River and are suspected to breed upriver.

Parry Inlet, Denmark

A pair of White-bellied Sea-Eagles including juveniles, are seen here regularly. They are suspected to be breeding nearby, but the nest has not been located.

Albany, Torbay

There was a White-bellied Sea-Eagle nest which was active in 2020, at Torbay Inlet near the Balla Balla River next to Mannerup Lagoon. This nest was not located during a search on 10 December 2023; however, the birds may be breeding nearby.

Summary

This field study has shown that there are more nesting sites on the mainland in southwest WA than were previously known. Adult birds are sedentary with large, permanent home ranges. Their nesting sites are well hidden, often in the forks of large trees. These sites are close to a large water body (lake, river or inlet) which has a large waterbird population or waters rich in fish. Some sites are in urban areas or close to roads but most sites are in more remote locations. Where birds have changed nesting sites, the new nest site was close by.

The White-bellied Sea-Eagle is usually monogamous and pairs long-term, for the life of the partner (Debus 2017). It is a winter breeder. On the Swan River Coastal Plain egg-laying takes place between early June and early August. They have a 42-day incubation period and an 83-day hatching to fledging period. These parameters were used to arrive at an estimated egg-laying date (Dennis *et al.* 2012; Debus 2017). Over the 2023 breeding season, 14 fledglings were recorded, with four pairs raising two fledglings and six pairs raising one nestling.

Young birds are provided with food by the parents for up to 2 months after fledging and will remain in the nest area to roost with the parents for 5–6 months (Fig. 5). Juveniles may be tolerated in or revisit the natal territory and nest up to the start of the next nest-building/renovation season (Debus 2017).

Field observations and prey remains under nests showed that White-bellied Sea-Eagles are opportunistic feeders. Prey includes Eurasian Coot (*Fulica atra*), young Australian White Ibis (*Threskiornis molucca*), Silver Gull (*Chroicocephalus novaehollandiae*), Musk Duck (*Biziura lobata*), Cormorant and Oblong Turtle (*Chelodina oblonga*) (Mawson 2023). At the base of the Bunbury nest site two dozen turtle shells and six Cobbler (*Cnidoglanis macrocephalus*) skulls were found during winter 2021 (Singor 2021). A bird picked up a Pouched Lamprey (*Geotria australis*) from the mouth of

Figure 5. A Juvenile White-bellied Sea-Eagle recently fledged at Nornalup Inlet. Photo: Philippa Beckerling.

the Warren River (T. Dearle, pers. comm.). There is a record of an adult feral goose being taken as prey (Mead-Hunter 2003), and they have been seen to chase and harass Ospreys to drop their catch (C. Corker, pers. comm.). There was a sequence of photos on Facebook by Sarah Walton, taken on 10 June 2023, showing a bird at Lake Joondalup trying to catch a Yellow-billed Spoonbill (*Platalea flavipes*) in flight. They will also feed on carrion, such as a dead sheep at Margaret River (Wilder 2023), and a kangaroo carcass near Poison Gully, Brookton Highway, Karragullen (T. Kirkby, pers. comm.). At the Houtman Abrolhos, White-bellied Sea-Eagle predominately feed upon seabirds as well as the Tammar Wallaby (*Notamacropus eugenii*) on East and West Wallabi Islands and the occasional fish (Surman 2022).

An interesting White-bellied Sea-Eagle hunting sequence was observed at Parry Inlet, Denmark (P. Burgess pers. comm.):

"On Wednesday 27 December 2023, a flock of 50 or so Australian White Ibis suddenly took to the air. I looked around and saw a couple of adult White-bellied Sea-Eagle charging into the flock, hunting in tandem. The hunt went around a headland and out of my view but then when they came back around the corner, they had managed to isolate one of the Australian White Ibis who headed for a dead branch in the water with the hope of a bit of shelter. There appeared to be some blood on the Ibis's neck. I think one of the White-bellied Sea-Eagle must have already hit it. The injury to the Ibis was obvious and a Swamp Harrier was hovering around as the White-bellied Sea-Eagles sat on the branch above their prey. The White-bellied Sea-Eagle then took off and left the Ibis alone only to return 20 minutes later. This behaviour happened 4 or 5 times where the White-bellied Sea-Eagle would leave, usually for 15 or 20 minutes and then return in an attempt to grab the Ibis that failed and remained just perched above the hapless creature. This could last half an hour. In the end

the White-bellied Sea-Eagle finally secured the poor Ibis and the fatal blow was as a bite to the neck. Then, once again, assuming the Ibis was now dead the White-bellied Sea-Eagles took off and left the Ibis just hanging there, returning half an hour later and then 10 mins after that it was joined by the other White-bellied Sea-Eagle. This whole saga took three and a half hours to unfold. When I left there was no White-bellied Sea-Eagle to be seen and the dead Ibis was floating in the water snagged on the branch."

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From Field and Study

Glauert's (1950) Olive Python (*Liasis olivaceus*) record for the Murchison: evidence for the mislabelling of a Kimberley *L. o. olivaceus* specimen originating from Mt Anderson in 1927

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In the first handbook of snakes for Western Australia (WA) published in 1950, the Rock Python or Water Python [now Olive Python] (*Liasis olivaceus*) was stated to have a distribution encompassing the north of the State and stretching as far south as the Murchison district (Glauert 1950). This range description remained unchanged for subsequent editions of this handbook (Glauert 1957, 1967). The *L. olivaceus* species-group for WA was revised in 1981 by Laurie A. Smith of the Western Australian Museum (WAM). He described a new subspecies, the Pilbara Olive Python (*L. o. barroni*), endemic to the Pilbara and northern parts of the Gascoyne bioregions in WA (Pearson 1993). *Liasis o. barroni* was distinguished from the northern populations of *L. o. olivaceus* based on having fewer midbody scale rows (58–63 versus 61–72) and a greater number of ventral scales (374–411 versus 355–377) (Smith 1981).

For this revision, Smith examined all *L. olivaceus* vouchers held by the WAM (Ellis 2015). He remarked that the Murchison record was likely based on a skin (WAM R2760) sourced from the Zoological Gardens South Perth (Perth Zoo), purported to have originated from Cue (i.e. well south of the known range of the species). This specimen had 355 ventrals and 68 midbody scale rows, meaning it could only have come from the range of *L. o. olivaceus* (Smith 1981). The WAM historical specimen register and accession data provide a date of 12–17 August 1929 and list it as an adult. In the remarks column, it was noted as a dubious locality [Cue] for this species. There was no mention that it was acquired via the Perth Zoo, presumably Smith (1981) obtained this information from the specimen's label. The whereabouts of this specimen in the WAM collection is currently unknown. We examined if there was a plausible alternative collection location for this *L. o. olivaceus* specimen (R2760).

At the time, stories of snakes/pythons were popular in newspapers, including the documenting, collecting and donating of specimens (live or dead) to the Perth Zoo and WAM. Digitized historical newspapers for WA were searched using the 'Trove' search engine (https://trove.nla.gov.au/). Searches were limited to the period of 1920–1930 using a range of terms, singularly or in combination; 'snake',

'python', 'rock python', 'Glauert', 'zoo', 'museum', 'Cue', and 'Kimberley'. The category was set to 'Article' for these searches.

Three articles of relevance were located. One from April 1928 mentions the WAM received 11 snakes from Mrs. O. Cusack of Tambrey Station, near Roebourne in the Pilbara, including a young Brown Rock Python (Glauert 1928). This specimen was identified as a juvenile *L. o. barroni* and lodged in the collection (R2248), although it was later discarded due to poor condition (Ellis 2015). We found no other records of Rock or Olive Pythons being sent to the Perth Zoo or WAM from 1920 to 1930. The other two articles relate to a Carpet Snake (Python) collected on Lakeside Station near Cue by Aboriginal people in October 1928. Mr Bert Clarkson took the live python, measuring about eight feet in length into Cue, forwarding it to the Perth Zoo (Anonymous 1928a). The safe arrival and addition of this Carpet Python to the snake house at the Perth Zoo was subsequently confirmed (Anonymous 1928b).

An examination of the Perth Zoo donors' book mentioned the donation of two Olive Green Rock Pythons shipped from Derby, donated by Mr Rose Jnr received on 5 December 1927. The Annual Report of 1928 confirmed this donation stating: "*Mr Rose presented a fine pair of Olive Green Pythons from his station in the North*" (p. 3; Zoological Gardens South Perth 1928). For the 1928–29 financial year there were eight native and 18 exotic pythons, order Ophidia in the Zoo (Zoological Gardens South Perth 1929). The Rose family were prominent pastoralists in the Fitzroy valley of the Kimberley, with at least three families present on various stations in 1927 (Staples 1988; Solonec 2004). The use of 'Jnr' by the donor allows him to be identified as George Canler (Canny) Rose Jnr, who ran Mt Anderson Station for many years (homestead: -18.0349°S, 123.9285°E; Staples 1988). G.C. Rose Jnr also collected plant and animal specimens that were lodged at the WA Herbarium and Museum from Mt. Anderson in the 1950s. Other articles, including photographs, confirmed the occurrence of 'Rock Pythons' (*L. o. olivaceus*) at Mt Anderson (McKinnon 1950; Atkinson 1954; Ford 1955).

The most plausible explanation for the provenance of the *L. o. olivaceus* specimen (R2760) identified by Smith (1981) is that one of the two Mt Anderson pythons died following ~20 months at the Perth Zoo in August 1929. Zoo staff had a stock of at least eight native pythons at the time, mistakenly labelling this deceased *L. o. olivaceus* with the locational details of a Carpet Python that had arrived nine months earlier from Cue (Anonymous 1928b).

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From Field and Study

A rare observation on the breeding cycle of the Pilbara leaf-nosed bat (*Rhinonicteris aurantia* – Pilbara form)

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The Pilbara leaf-nosed bat (*Rhinonicteris aurantia* – Pilbara form) is a geographically isolated population of the orange leaf-nosed bat (Armstrong 2001). It is listed as Vulnerable under the Commonwealth's Environment Protection and Biodiversity Conservation Act 1999 and the Western Australian Biodiversity Conservation Act 2016.

Information regarding reproduction of the species is limited to populations in the Kimberley and Northern Territory (Churchill 1995). Within these populations the reproductive cycle is defined as seasonally monoestrus (a single estrus event during a breeding season) (Churchill 1995). Reproductive patterns of the Pilbara form are assumed to be similar (Armstrong 2001); however, variation is possible due to the climatic differences between the regions. In the Northern Territory population, mating typically occurs in July and early August (Churchill 1995; DAWE 2020), gestation lasts for approximately 150 days before females give birth from the beginning of December (Armstrong 2001). Birth and lactation therefore coincide with the wet season, when there is a peak in food availability (Churchill 1995). Armstrong (2001) recorded females with reddened nipples surrounded by bare patches in mid-March suggesting young were large enough to be left in a roost unattended. A rapid growth period means young are almost indistinguishable from the adults two months after birth (Churchill 1995, 2008).

A cave located near Marble Bar in the Chichester subregion of Western Australia's Pilbara bioregion is considered a permanent diurnal roost, that has been verified by year-round ultrasonic recordings. The roost consists of a constricted entrance (approximately 9 m wide) opening into a large chamber approximately 50 m deep. A second smaller, upper chamber (approximately 5 m deep and 1.5 m high) located above and to the rear of the main chamber, is considered the main roosting location for Pilbara leaf-nosed bats.

On the evening of 10 March 2021, the upper roosting chamber was entered to install microclimate logging equipment. Upon entering the roosting chamber, approximately 300 adult bats were seen and began to leave due to the disturbance. Most of the adult bats relocated into the main chamber with only a few remaining in the upper roosting chamber. At this stage approximately 10–12 juvenile Pilbara

leaf-nosed bats were seen attached to the side wall of the cave. These individuals were identified as juveniles because of their small size, lack of fur, skin translucency and underdeveloped features (Fig. 1). It is believed that the juveniles were non-volant, as a single individual attempted to fly, however, it was unable to remain airborne. More juveniles may have been in the upper roosting chamber; however, further investigation did not occur in order to prevent additional disturbance to the colony. The juveniles were identified as Pilbara leaf-nosed bats as other species have not been recorded in that section of the roost, and exhibited suitable size and roosting behaviours, in comparison with other cave dwelling species in the region.

Rainfall during key periods of the species breeding cycle during and preceding 2020 to 2021 was within normal ranges and unlikely to have altered breeding activity. Given the complimentary observation by Armstrong (2001), of lactating females in March 1998, the finding of juvenile Pilbara leaf-nosed bats in March, could be considered within normal reproductive ranges.

These findings have implications for survey and research throughout the Pilbara region. To minimise disturbance to the species we recommend that breeding caves are not entered between mid-December and the end of March. It is also recognised that further work on the

Figure 1. Juvenile Pilbara leaf-nosed bats attached to the side of cave wall. Photo: A. Kimpton.

breeding cycle and general ecology should be undertaken for this isolated population.

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Book Review

Field Guide to the Reptiles of the Northern Territory

Chris Jolly, Brendan Schembri & Stewart MacDonald. 2023. CSIRO Publishing, Melbourne, Victoria (https://www.publish.csiro.au). 400 pp. Paperback. AU $49.99. ISBN: 9781486312689.

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Australia's reptile diversity is one of the most unique and impressive throughout the world, with each state or territory possessing their own iconic assemblages. The high levels of diversity often impede the development of Australia-wide or even state field guides, with content limitations being restrictive in accommodating the nearing 1,150 species. Only two publications currently offer Australia-wide coverage, Steve Wilson and Gerry Swan's *Complete Field Guide to the Reptiles of Australia* (now 6th edition) and Harold Cogger's *Reptiles and Amphibians of Australia* (now 7th edition). The former, a compact 574 page, plastic-shielded field guide, though sometimes content limited, is a compromise to maintaining a small profile. The latter, a hefty 1096 page 3 kg reference book, loaded with content and large photos, often destined for the office or lab bookshelf due to its size.

In what could be argued the best contribution to Australian herpetological literature in 2023, *Field Guide to the Reptiles of the Northern Territory* takes the next step in providing an impressive state/territory-specific field guide presenting the offerings of the Northern Territory (NT) to the world. To date, the only NT reptile-specific field guide was Paul Horner's 1992 *Skinks of the Northern Territory*, making a field guide covering all reptile taxa well overdue and duly awaited. The authors of *Field Guide to Reptiles of the Northern Territory* have managed to achieve the best of both worlds with a compact field and office/lab-friendly resource with maximum content. At 424 pages long it is lightweight for the field but contains more than enough information to take pole position in the office or laboratory.

The authors, Brendan Schembri, Chris Jolly and Stewart MacDonald, need no introduction, all three are well-known Australian herpetologists and reptile biologists will no doubt recognise their names from one of their many photographic contributions of Australian wildlife. Collectively the trio have probably covered most of the country in search and study of reptiles and other wildlife, which has led to them having probably photographed close to every described reptile in Australia, and many yet to be described. Their passion in herpetology is hard to compete with, and their dedication is eminent through the production of this book and contributions more broadly to research.

The iconic Oenpelli python (*Nyctophilopython oenpelliensis*) adorns the cover, taking pride of place with smaller images of a thorny devil (*Moloch horridus*), northern knob-tailed gecko (*Nephrurus sheai*) and spotted tree monitor (*Varanus scalaris*), all from author Brendan Schembri, making the book instantly appealing. It is just a small taste of what to expect image-wise throughout the book.

A concise and reflective foreword by Australian herpetological royalty Paul Horner, details his own experience working on NT reptiles, and the lack of a field guide to date. Proceeding is a lengthy list of acknowledgements, reflective of the reach the authors have in Australian herpetology. The preface succinctly provides background information on the book, including taxonomic classification (and the age old question of what is a species), common and scientific names (including the problematic dual nomenclature often faced in Australian herpetology), identification and details on the dichotomous keys and species profiles provided in the book. The introduction provides a brief overview of NT reptiles and the history of descriptions, followed by a summary of regional climate, habitats and threats.

Species profiles for 390 species are arranged taxonomically, with a summary provided for each family and genus. This includes species profiles for all 368 species known to occur in the NT, and the excellent addition of a further 22 species not previously recorded but are known to occur in relatively close proximity to the NT border which are suspected to occur. Of note are the dichotomous keys and detailed diagnostic illustrations scattered throughout the book with each genus and some family accounts, providing a valuable reference point and step-by-step guidance where needed.

Species profiles are organised alphabetically within each genus, with common name and Latin name with species authority heading each profile. The inclusion of species authorities make this a very handy reference for those undertaking taxonomic studies, where users often need to refer to original species descriptions, or even those interested in learning more about the species. While references for every species description are not provided, making for a rather unwieldy addition, they do provide an excellent reference point for users. Each species profile comprises a succinct description of the species' carapace length (CL, for turtles), snout-vent length (SVL, for non-varanid lizards) and total length (TL, for crocodiles, varanids and snakes), scale configuration and counts (midbody and ventrals) where applicable, colour and pattern, with key diagnostic characteristics in bold for quick reference. Another great addition are the ventral scale counts provided for snakes, an extremely useful yet often overlooked diagnostic regularly excluded from field guides. The succinctly written description texts are very well written and, along with keys and illustrations if needed, provide sufficient information to diagnose and/or confirm identification with ease and a high degree of confidence. Where subspecies exist, their distribution and diagnostics are provided. A brief notes section details the distribution and habitats of each species and any key behavioural or ecological information or taxonomic notes, along with any conservation status listings under federal and/or state/territory legislation, or the IUCN Red List of Threatened Species. Any similar species are also listed for comparison. Associated with each

species is a small but still very easily readable distribution map with a red coloured polygon displaying the species distribution, with any unknown or uncertain distributions displayed by a small question mark.

One of the biggest highlights in the book is the amazing selection and quality of photographs, with each species represented by at least one high quality photo showing specimens in a natural or semi-natural pose with natural backgrounds. All labelled with the species Latin name, locality and photographer. Where a subspecies or a high degree of morphological variation occurs, multiple photos have been used (e.g. Bynoe's gecko, *Heteronotia binoei*). The use of smaller photographs has allowed for close placement within relevant species text and maximised the use of the space on each page. The authors achieved in-life photographic representation of nearly all species, with only a few having to be represented by museum specimens: three sea snakes (black-headed sea snake, *Hydrophis atriceps*; Belcher's sea snake, *H. belcheri*; dwarf sea snake, *H. caerulescens*), two blindsnakes (miner blind snake, *Anilios fossor*; Yirrkala blind snake, *A. yirrikalae*) and a dragon (even-scaled earless dragon, *Tympanocryptis uniformis*).

The guide concludes with a section on venom and snakebite first aid by Timothy Jackson, providing essential information for anyone to refer back should that undesirable situation occur. Following are the glossary and abbreviations, references and suggested reading and separate indexes for common and Latin names.

Overall, *Field Guide to the Reptiles of the Northern Territory* would have to be one of the best Australian field guides produced, and will likely set a new benchmark in regional field guides. The highly desirable detail often lacking in field guides is not only in abundance, but beautifully paired with high quality photos representing almost all species included, some unavoidably having to be museum specimens. While it was hard to fault the content of the book in any form, the only concern is the lack of any protection to the paperback covers, which probably won't bode too well with often unforgiving field use, particularly in the NT. By all means, not a deal breaker as the book feels well-constructed overall, but something that would be desirable for the inevitable second edition wish list. In the meantime, the most logical fix is to purchase a copy for the field and one for the bookshelf. Given the quality of the book, it's worth it.

Unfortunately, like all field guides, particularly in Australia, the frequent taxonomic works across most reptile groups often leaves field guides out of date, at or soon after publication. While *Field Guide to the Reptiles of the Northern Territory* has managed to make it nearly 12 months since publication without a new species rendering it out dated, it will likely come soon enough. On the upside though, if the high standard of the book is maintained in subsequent editions, you will be hard pressed to be annoyed having to buy a new edition.

If you have even the slightest interest in reptiles and live, work or are planning a visit to the NT then this field guide is a must have. In the unfortunate event that you don't have the opportunity to visit the NT, it is still an extremely useful resource that'll take pride of place on the bookshelf, when it's not regularly being pulled off to peruse the amazing reptile offerings the territory has to offer. It is an essential to any library containing Australian reptile or ecological literature.